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No. ....

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# United States Circuit Court of Appeals

For the Ninth Circuit

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MINERALS SEPARATION, LTD.,  
ET AL,

*Appellees,*

vs.

BUTTE & SUPERIOR MINING  
COMPANY,

*Appellant.*

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## Transcript of Record

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### Volume 6

(Pages 2869 to 3540, Inclusive)

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UPON APPEAL FROM THE UNITED STATES  
DISTRICT COURT FOR THE DISTRICT  
OF MONTANA

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Samuel P. Sadtler

"Everson," we have no forms of apparatus described. We have several very important statements of conditions. The ore was crushed and passed through a 60 mesh screen dry and thoroughly mixed with black, thick oil, presumably a petroleum product. To water heated to near boiling was added enough sulphuric acid to give it a tartish taste. This acid and water was then mixed with the mass of oil and ore. Now, there is entire absence of any account of the form of apparatus or how the agitation was carried out, but the result alone is stated. A thick scum of sulphurets rose to the surface and was skimmed off, leaving the hitherto black ore as white as snow, in fact pure silica. These are the vital elements in this statement.

Q. 162. Do the results stated in the sentence you have just quoted beginning "a thick scum"—Does that convey any information regarding the operating process?

A. That shows I think, clearly that it was the same process as would have been carried out with the same apparatus which is figured in this other publication, and the results would have been the same as there obtained. The scum is the froth in this case.

Q. 163. If you will refer once more to the Everson patent, page 607 of defendant's record in the Hyde case, on page 1 of the patent, beginning at line 17, extending to line 20, the same page, beginning at line 81 extending down to about 86, the patentee makes statements regarding the character of oils adapted for her process. Will you state how extensive a category of

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oily substances is set forth in the language used in these passages?

A. The list is a very comprehensive one. In line 17 we have the expression "a fat or an oil, either animal, mineral or vegetable, or a fatty constituent or acid or animal, vegetable mineral or oil or any constituent of a mineral oil." These terms cover all of the animal and vegetable oils and their constituents like oleic acid, which is a fatty acid derived from an animal and vegetable oil. And that covers all of the petroleum fractions because "any component of a mineral oil" is there mentioned. And the same thing is used with a little more expressive statement of particular oils, in line 80:

"I used petroleum and one of its several components, viz., paraffine oil." But the whole range of petroleum constituents can be covered by that earlier language, also tallow in melted form, lard, lard oil, red oil, meaning thereby impure oleic oil, cottonseed oil, castor oil, sperm oil, linseed oil and some combination of these with each other. That gives us a range of fatty oils or what might be called fixed oils, of both animal and vegetable origin. It does not specify an essential oil or one of the terpene type oil, but that is covered under the broad statement "fat or oil, either animal, mineral or vegetable."

MR. SCOTT: I think now, as the continuity of our case has been broken a little through necessity, I will discontinue the examination of Dr. Sadtler for the time being and put on another witness in order to get the things before the court that the doctor will want to

John Warne Phillips.

refer to before he finishes, and opposing counsel may either cross examine now or later as they choose.

MR. WILLIAMS: I think it will be better to postpone the cross examination until the completion of the deposition, as matters stand. Of course there may be some incidents that require it.

THE COURT: This promises to be a long case and you ought to have your witnesses in order and know what they are going to testify to and have everything ready.

MR. SCOTT: The evidence is all ready. It is simply the mechanical work that is necessary.

WITNESS TEMPORARILY EXCUSED.

JOHN WARNE PHILLIPS, a witness called on behalf of the defendant, being first duly sworn testified as follows:

DIRECT EXAMINATION,

BY MR. SCOTT:

Q. 1. State your full name.

A. John Warne Phillips.

Q. 2. Will you kindly state your occupation?

A. I am connected with Mariner & Hoskins, chemists and engineers of Chicago, at the present time, and represent them here now at this case.

Q. 3. And what is the nature of your duties or profession?

John Warne Phillips.

A. I graduated from Princeton and spent two years there as a post graduate and was instructor there for three years and then I accepted a position of professor of chemistry and physics in the University of Nevada and taught there for ten years and then I carried on metallurgical operations in plants of my own, and for several years I was manager of the Overland Mining Company, of Gold Hill, Nevada, and for four years I have been connected with the engineering firm in Chicago of Mariner & Hoskins, as chemical engineer.

Q. 4. Have you made any investigations of the character of froths produced in the flotation process?

A. I have.

Q. 5. Just briefly, without going into details at present, just state the nature of the operations you carried out.

A. I used several—I have used three varieties of oils, practically on the same charge, on a laboratory scale. The charge used was 60 grams of ore, 250 c. c. of water and copper sulphate in the proportion of one-fifth of a pound of copper per ton of ore, and sulphuric acid in the proportion of 8 lbs. of 60° Be. sulphuric acid per ton of ore. I added the pulp of course first to the vessel and then the water and then the copper sulphate and then the acid and agitated for one-half minute so as to thoroughly stir the pulp with the solution and then I add the oil and agitate it for eight minutes, and most of the tests, most all of the tests were carried on in that method, that procedure.

John Warne Phillips.

Q. 6. What was the ore that you used?

A. The ore used was a Butte & Superior ore, I think mill heads, lot No. 2. It assayed 16% of zinc, if I remember rightly, about—Its fineness was 6% on an 80 mesh and about 60% through a 200 mesh.

Q. 7. And what kind of an apparatus did you use for these experiments?

A. We used an ordinary soda fountain or bar mixer, electric mixer, and for the vessel we used a rectangular-shaped vessel, I think used for a battery jar, about  $5\frac{1}{2}$  inches high, 2 inches wide and about  $2\frac{1}{2}$  long, that is, a rectangular shape.

Q. 8. And you made photographs, did you, of these froths?

A. Made photographs.

Q. 9. Will you describe the character of the different photographs you made, the views?

A. We made three series of photographs. The first was taken, a photograph of the froth through the side of the vessel and a magnification of 15 diameters, or that would be 225 times, magnified 225 times. And all photographs of that character are labeled No. 1, or series 1.

Now, series 2, photographs were made through the sides of the vessels in the same way, but a magnification of five diameters or 25 times; and photographs No. 3 series, 3 was made of the top of the froth by using a prism and taking the top view of the froth. They were not magnified, supposed to be normal. Now, these magnifications are not absolute, but very near.

John Warne Phillips.

We determined the magnification by taking a photograph of a scale in the place where the froth or object was, and measuring the image of this scale, on the ground plate of the camera, and taking the ratio between those two. That is the method we obtained of magnification, particularly five magnification and fifteen magnification.

Q. 10. Were you present throughout those operations of making these different froths, and supervising it or performing it?

A. Yes, at all times.

Q. 11. And the same is true of the making of the photographs?

A. The making of the photographs; I was present when the exposures were made and instantly after the exposure I put a number on the negative before it was printed.

Q. 12. I will show you some of these photographs and ask you if you can identify them. The distinguishing numbers are different in each case?

A. Yes.

Q. 13. So if you identify them by number it will be definite, will it?

A. Yes.

Q. 14. Now, will you kindly state what this photograph bearing the number 16-3 is?

A. That is a top view of froth containing one-tenth of 1% oil, mixture No. 3.

Q. 15. And will you state what that oil mixture is?

A. What it comprises?

John Warne Phillips.

Q. 16. What oils and what proportions?

A. I can't remember that.

Q. 17. Refer to your notes.

A. The oil mixture contained 70% crude fuel oil, 18% yaryan pine oil and 12% refined kerosene.

Q. 18. And the proportion is one-tenth of 1%?

A. Yes.

Q. 19. Now I hand you another one which is marked with the number 17-3 and ask you to identify that and state what that represents.

A. 17-3 is the same but contains three-tenths of one per cent. of oil mixture.

Q. 20. Of the same oil mixture?

A. Oil mixture No. 3.

Q. 21. Now I hand you another photograph which bears the designation 1-3.

A. That is a photograph, top view, of froth containing 4/10 of 1% oil mixture.

Q. 22. The same oil mixture?

A. No, not the same oil mixture. The oil mixture of this other varies just slightly in containing 17% yaryan pine oil and 13% kerosene instead of 18% and 12%.

Q. 23. Now I hand you a photograph marked 2-3.

A. That is a top view of the same character of charge but containing one-half of 1% of oil mixture.

Q. 24. What oil mixture was that, the same as number—

A. The same as No. 1-3.

John Warne Phillips.

Q. 25. Now I hand you another photograph marked 3-3.

A. That is a top view of froth containing six-tenths of 1% oil mixture.

Q. 26. The same oil mixture?

A. The same oil mixture as No. 1, 2 and 3.

Q. 27. I hand you another photograph designated 4-3.

A. That is the same oil mixture. The same view, but containing 1% of oil mixture.

Q. 28. As one oil mixture?

A. As one oil mixture.

Q. 29. The same oil mixture as 1, 2 and 3?

A. Yes, the same charge.

Q. 30. Now I hand you another photograph bearing designation 8-3.

A. That is the same as—top view of froth and containing 1½% oil mixture, same oil mixture.

Q. 31. Photograph bearing designation 5-3.

A. That is a top view of froth containing 1½% of the same oil mixture.

MR. SCOTT: I think I will offer the set right now, to avoid confusion. I offer in evidence the photographs just identified by the witness and ask that each be marked as a separate exhibit in the following order:

Photographs 16-3, 17-3, 1-3, 2-3, 3-3, 4-3, 8-3, 5-3.

The photographs were admitted in evidence and marked DEFENDANT'S EXHIBITS 52 to 59 inclusive.

John Warne Phillips.

Q. 32. MR. SCOTT: Mr. Phillips I hand you a photograph marked 16-2 and ask you to identify and describe what it represents.

A. That is a side view of the froth taken from the sides of the vessel containing one-tenth of 1% of oil mixture No. 3 and a magnification of five diameters or 25 times.

Q. 33. You say oil mixture No. 3; is that the one you described before?

A. The first, yes.'

Q. 34. That is the first oil mixture you described before?

A. Yes.

Q. 35. This picture was taken how, did you say; through the side?

A. Through the side of the vessel.

Q. 36. Of the glass jar in which it was made?

A. Yes. And the dark line below shows water below the froth, this dark spot?

Q. 37. And how high that line of froth extends on the picture?

A. The froth extends along this line here, right along here, and all of this froth, all this frosting above is the creep on the side of the vessel.

Q. 38. Will you please make a mark on the photograph, a letter or a number or something to show the upper boundary of the froth?

A. This froth was only a quarter of an inch in depth, consequently the froth in the picture should not

John Warne Phillips.

be over an inch and a quarter in depth to be five diameters.

MR. SCOTT: The witness has made a mark on the photograph and written the word "top" to indicate the upper surface or edge of the froth.

Q. 39. Now, what is that appearance above the top of the froth that is indicated in the upper part of the photograph?

A. That is the creeping of the oil and ore on the inside of the vessel, up on the inside of the vessel, during agitation. When it settles down it comes down and leaves this frosting on the inside of the vessel.

Q. 40. It is merely the dirty side of the vessel?

A. Dirty glass inside.

MR. SCOTT: I offer this photograph marked 16-2.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 60.

Q. 41. MR. SCOTT: I hand you another photograph marked 17-2 and ask you to state what that represents.

A. This represents the same view and the same oil mixture but contains three-tenths of 1% of oil.

Q. 42. Of the same mixture as that of No. 16-2?

A. Yes, of No. 16-2.

Q. 43. Will you indicate on this photograph also the top of the froth if it shows there or does it extend away to the top of the picture?

A. No, it doesn't extend away to the top of the picture.

John Warne Phillips.

Q. 44. Is it possible to tell just where the froth does leave off and where the dirty side of the jar begins?

A. It is difficult in this case. I think the froth is about along on this line, right in through there; this represents this top of the froth. The average depth of the froth was  $2\frac{1}{2}$ —or one-half an inch, I should say. One-half inch magnified then, five times would make it  $2\frac{1}{2}$  inches deep, so these marks through there, the openings, to my mind would indicate the top of the froth.

Q. 45. Just make a mark on that similar to the other one.

(Witness marks the photograph.)

MR. SCOTT: I offer this photograph marked 17-2.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 61.

Q. 46. I hand you photograph marked 1-2 and ask you to identify it.

A. This is the same view magnified five diameters, 25 times, but contains four-tenths of 1% oil mixture, the second oil mixture.

Q. 47. Can you indicate on this photograph about the position of the upper surface of the froth?

A. I think this is along there near the top of the picture.

Q. 48. This one you named the amount of oil, didn't you, as four-tenths of 1% of the second oil mixture?

John Warne Phillips.

A. Yes, four-tenths of a per cent.

MR. SCOTT: I offer this photograph bearing No. 1-2.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 62.

Q. 49. MR. SCOTT: I hand you another photograph bearing No. 2-2 and ask you to identify it and describe it.

A. This is the same view taken through the side of the vessel magnified 25 times and containing one-half of 1% of oil mixture.

Q. 50. Can you identify the position of the top of the froth?

A. I have.

Q. 51. By an ink mark and the word "Top"?

A. Yes.

MR. SCOTT: I offer this photograph marked 2-2.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT 63.

Q. 52. I hand you a photograph marked 3-2?

A. This was taken through the side of the vessel, magnified 25 times, and contains six-tenths of one per cent oil mixture. The froth extends nearly to the top of the picture.

MR. SCOTT: I offer this photograph in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 64.

John Warne Phillips.

Q. 53. I will ask you to describe this photograph, marked 4-2?

A. This was taken through the side of the vessel, magnified 25 times, and contains one per cent of the oil mixture.

Q. 54. The froth extends to the mark you have just put on the picture, does it?

A. Yes.

MR. SCOTT: I offer the photograph marked 4-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 65.

Q. 55. I hand you photograph marked 8-2 and ask you to describe it?

A. This is taken through the side of the vessel, magnified 25 times and contains one and a quarter per cent oil mixture.

Q. 56. When you say contains one and a quarter per cent, you mean, do you not, that the froth was made by using one and one quarter per cent of oil relative to the weight of the ore?

A. Yes, sir.

Q. 57. You don't mean that the froth itself contains one and a quarter per cent?

A. No; the charge was made up by using one and a quarter per cent of oil to the amount of ore used.

Q. 58. Does the froth extend to the point you have designated on this photograph?

John Warne Phillips.

A. To the top, yes, sir.

MR. SCOTT: I offer the photograph 8-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 66.

Q. 59. I hand you a photograph marked 5-2 and ask you to describe it?

A. This is taken through the side of the vessel, magnified 25 times, and the charge was made up to contain one and a half per cent of the oil mixture.

Q. 60. Of the same mixture?

A. Of the same mixture as the preceding.

MR. SCOTT: I offer this photograph marked 5-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 67.

Q. 61. Now, Mr. Phillips, there was a little change in the oil mixture, as I remember it, the photographs numbered 16 and 17—

A. Were made from the oil mixture No. 3.

Q. 62. And the photographs 1, 2, 3, 4, 8 and 5—

A. Were made up from another oil mixture which was not numbered, just labeled oil mixture, and that oil mixture contains 70 per cent of crude fuel oil, 17 per cent of Yaryan pine oil and 13 per cent of refined kerosene.

Q. 63. And you described the mixture that was used before for 16 and 17?

John Warne Phillips.

A. I did, yes, sir, mixture No. 3.

Q. 64. I hand you a photograph marked 16-1, and ask you to state what it represents?

A. This is a photograph of the froth taken through the side of the vessel, magnified 225 times.

Q. 65. That would be 25 diameters?

A. Fifteen diameters; and it contains one-tenth of one per cent of oil mixture No. 3. All pictures marked 16—16-1, 16-2, and 16-2—were taken from the same experiment or the same froth.

Q. 66. And the numbers 1, 2 and 3 indicate?

A. Indicate the series of the pictures and the first number, 16, represents the test.

Q. 67. And all pictures numbered 1 are what kind of views?

A. Taken through the side of the vessel, magnified 225 times. Pictures marked 2 are taken through the side of the vessel, magnified 25 times, and all pictures numbered 3 represent the top view of the vessel of natural size.

Q. 68. This 1, 2 and 3 that you just referred to is the second of the two figures which appear on the photograph?

A. The second numerals.

Q. 69. And the first numeral appearing on the photograph designates the particular test?

A. The particular test and the particular charge.

Q. 70. And wherever the same number is the same on two or three photographs, they are photographs of the same test?

John Warne Phillips.

A. Of the same test, the same froth.

Q. 71. You just gave the proportion of the oil?

A. Yes, one tenth.

Q. 72. Does that froth extend clear to the top of the picture I hold in my hand now?

A. I should say nearly; it is perhaps to there.

Q. 73. Will you explain to the court, by reference to these experiments which were performed yesterday —these illustrations of the California Journal which are now standing here—explain to the court just what the indefiniteness is in telling where the froth leaves off at the top?

A. Here is an example here; taking the froth here —that would occur in the picture, and still the top of the froth would be down somewhere here, and we have to take really the measurement of the thickness of the froth.

THE COURT: That was made by the court tipping it up a while ago. You mean the upper part?

A. The upper part, yes, sir.

MR. SCOTT: I offer this photograph marked 16-1 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 68.

Q. 74. I hand you another photograph marked 17-1. Please describe that.

A. 17-1 is a side view, taken through the vessel, magnified 225 times. The charge was made up of three-

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tenths of one per cent oil mixture No. 3 and the picture does not extend to the top of the froth.

MR. SCOTT: I offer this photograph marked 17-1 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 69.

Q. 75. I hand you another photograph marked 1-1, and ask you to describe it.

A. This is taken through the side of the vessel, magnified 225 times. The charge is made up of four-tenths of one per cent oil mixture. The picture does not extend to the top of the froth.

MR. SCOTT: I offer this photograph marked 1-1 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 70.

Q. 76. I hand you a photograph marked 2-1 and ask you to describe it?

A. Taken through the side of the vessel, magnified 225 times. The charge is made up of one-half of one per cent oil mixture and the photograph does not extend to the top of the froth.

MR. SCOTT: I offer in evidence photograph marked 2-1.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 71.

John Warne Phillips.

Q. 77. I hand you a photograph marked 3-1 and ask you to describe it?

A. Taken through the side of the vessel, magnified 225 times. The charge is made up of six-tenths of one per cent oil mixture, and the photograph does not extend to the top of the froth.

MR. SCOTT: I offer in evidence photograph 3-1.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 72.

Q. 78. I hand you a photograph marked 4-1.

A. Taken through the side of the vessel, magnified 225 times. The charge is made up of one per cent oil mixture. The photograph does not extend to the top of the froth.

MR. SCOTT: I offer in evidence photograph 4-1.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 73.

Q. 79. I hand you a photograph marked 8-1 and ask you to describe it?

A. Taken through the side of the vessel, magnified 225 times. The charge is made up of one and a quarter per cent oil mixture. The photograph does not extend to the top of the froth.

MR. SCOTT: I offer photograph 8-1 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 74.

John Warne Phillips.

Q. 80. I hand you a photograph marked 5-1 and ask you to describe it?

A. This was taken through the side of the vessel, magnified 225 times. The charge is made up of one and a half per cent oil mixture. The photograph does not extend to the top of the froth.

MR. SCOTT: I offer in evidence photograph marked 5-1.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 75.

Q. 81. I hand you a photograph marked 21-3 and ask you to describe what it represents?

A. 21-3 is a top view of the froth. The charge is made up of one-tenth of one per cent of oil mixture No. 3.

Q. 82. The photographs which I hold in my hand were they of the same tests?

A. No, no—I beg your pardon; instead of oil mixture, this is pine tar oil. The label of the oil it is made of is marked wood tar oil. One-tenth of one per cent wood tar oil.

Q. 83. You have stated that this was a top view?

A. Yes, a top view.

Q. 84. And these top views are substantially of the same size as the original?

A. Yes, the natural size.

MR. SCOTT: I offer this photograph 21-3 in evidence.

John Warne Phillips.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 76.

Q. 85. What can you say as to the character of the float in that photograph 21-3 which is now designated exhibit 76?

A. It was a very watery froth, and the bubbles were not persistent, and it was very tender and easily broken down, and disintegrated in a short time.

Q. 86. Did it seem to carry much mineral or little mineral?

A. It seemed to carry quite a great deal of mineral, it was heavily loaded.

Q. 87. Was it voluminous or heavy or thin?

A. No, it was very thin, only a quarter of an inch in depth.

Q. 88. I hand you a photograph marked 22-3; and ask you to describe what is there represented.

A. This is a top view of the froth, the charge made up of three-tenths of one per cent wood tar oil.

Q. 89. What can you say as to the character of a froth that was formed in that instance?

A. The froth was very easily broken down; the bubbles on top disappeared, but the froth was more voluminous than in 21-3.

MR. SCOTT: I offer this photograph 22-3 in evidence.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT No. 77.

John Warne Phillips.

Q. 90. I hand you photograph marked 9-3 and ask you what that represents?

A. This is a top view of the froth. The charge was made up to compose four-tenths of one per cent pine tar oil. Both of those oils were purported to be the same, but the vessel in which one was was labeled wood tar oil and the other pine tar oil.

Q. 91. Who was it that stated they were the same?

A. Mr. Dosenbach.

Q. 92. What can you say as to the froth that was formed in the instance of this photograph 9-3?

A. It was very permanent and persistent.

MR. SCOTT: I offer photograph 9-3 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 78.

Q. 93. This last one, 9-3, was made with four-tenths of one per cent oil?

A. Yes, sir.

Q. 94. The two of the previous ones of the series, 21-3 and 22-3 were made with respectively one-tenth and three-tenths?

A. Yes, sir.

Q. 95. I hand you photograph marked 10-3 and ask you to describe what is there represented?

A. The top view of the froth. The charge was made up to compose five-tenths of one per cent of pine tar oil.

MR. SCOTT: I offer this photograph 10-3.

John Warne Phillips.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 79.

Q. 96. I hand you photograph marked 11-3 and ask you to describe what it represents?

A. It represents the top view of the froth, the charge made up to compose six-tenths of one per cent of pine tar oil.

MR. SCOTT: I offer in evidence photograph marked 11-3.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 80.

Q. 97. I hand you photograph marked 12-3 and ask you to describe what is represented?

A. Top view of froth, the charge made up to compose one per cent of pine tar oil.

MR. SCOTT: I offer in evidence photograph 12-3.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 81.

Q. 98. I hand you photograph marked 13-3 and ask you to describe it?

A. This represents the top view of froth, the charge made up to compose one and a half per cent of pine tar oil.

MR. SCOTT: I offer in evidence 13-3.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 82.

John Warne Phillips.

Q. 99. I hand you photograph marked 14-3 and ask you to describe it?

A. Top view of froth; charge made up to compose two per cent pine tar oil.

MR. SCOTT: I offer in evidence photograph 14-3.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 83.

Q. 100. I hand you photograph marked 21-2 and ask you to state what it represents?

A. This represents the side view of the froth taken through the vessel, magnified 25 times, the charge made up to contain one-tenth of one per cent wood tar oil.

Q. 101. That is this photograph and the following ones of the series represent the same tests that were pictured in the top views which you have just described?

A. Yes, sir. The side view of 21 is the same as the top view of 21—the same froth.

Q. 102. It corresponds to 21, in the top views?

A. Yes, sir.

Q. 103. Will you indicate about where the top of that froth comes?

A. About there.

MR. SCOTT: I offer photograph 21-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 84.

Q. 104. I hand you photograph 22-2 and ask you what it represents?

John Warne Phillips.

A. Side view of froth taken through the vessel, magnified 25 times, and the charge made up to compose three-tenths of one per cent of wood tar oil.

Q. 105. You have indicated the top of the froth on this picture?

A. I have, yes, sir.

MR. SCOTT: I offer photograph 22-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 85.

Q. 106. Now, 21-2 and 22-2 that you have just described are side views of the same froth that was represented in the two top views that you described as being thin and tender?

A. They are.

Q. 107. I hand you photograph 9-2 and ask you to describe what is represented?

A. This is a side view of the froth, magnified 25 times, the charge composed of four-tenths of one per cent pine tar oil.

Q. 108. You have indicated the top of the froth?

A. I have.

MR. SCOTT: I offer photograph 9-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 86.

Q. 109. I hand you photograph 10-2 and ask you to describe it?

A. Side view of froth taken through the vessel, mag-

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nified 25 times and the charge is made up to contain one-half of one per cent, pine tar oil.

Q. 110. The top of the froth is about where on that picture?

A. About through here. That bubble extended up on the side of the vessel.

MR. SCOTT: I offer the photograph 10-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 87.

Q. 111. I hand you photograph 11-2 and ask you to describe it?

A. Side view of froth taken through the side of the vessel, magnified 25 times and the charge made up to contain six-tenths of one per cent pine tar oil.

Q. 112. You have indicated the top of the froth, have you?

A. Yes, as near as I can.

MR. SCOTT: I offer 11-2 photograph in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 88.

Q. 113. I hand you photograph marked 12-2 and ask you to describe it?

A. Froth taken through the side of the vessel, magnified 25 times, the charge made up to compose one per cent of pine tar oil.

Q. 114. The top of the froth appears about where as near as you can estimate?

John Warne Phillips.

A. About there.

MR. SCOTT: I offer photograph 12-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 89.

Q. 115. I hand you photograph 13-2 and ask you to describe it?

A. Photograph of the froth taken through the side of the vessel, magnified 25 times, the charge made up to contain one and half per cent pine tar oil.

Q. 116. You have indicated the top of the froth?

A. I have.

MR. SCOTT: I offer photograph 13-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 90.

Q. 117. I hand you photograph marked 14-2 and ask you to describe it?

A. This is a picture of the froth taken through the side of the vessel, magnified 25 times, the charge made up to contain two per cent of pine tar oil.

Q. 118. You have indicated the top of the froth.

A. I have.

MR. SCOTT: I offer photograph 14-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 91.

Q. 119. I hand you photograph 21-1 and ask you to state what is represented?

John Warne Phillips.

A. Photograph of froth taken through the side of the vessel, magnified 225 times and the charge made up to contain one-tenth of one per cent wood tar oil. The photograph does not extend to the top of the froth.

Q. 120. That is on account of this being more highly magnified, I presume?

A. Yes—well, it does go just to the top.

Q. 121. The top ends near the top of the photograph?

A. Yes.

Q. 122. This 21-1 indicates the froth that you have said was thin and tender?

A. Yes.

MR. SCOTT: I offer photograph 21-1 in evidence.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT No. 92.

Q. 123. I hand you photograph 22-1 and ask you to describe it?

A. This is a picture of the froth taken through the side of the vessel, magnified 225 times, the charge made up to contain three-tenths of one per cent wood tar oil. The froth extends beyond the edge of the photograph.

Q. 124. This also is one of the two froths that you referred to as being thin and tender, I think.

A. Yes, sir.

MR. SCOTT: I offer photograph 22-1 in evidence.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT No. 93.

John Warne Phillips.

Q. 125. I hand you photograph 9-1 and ask you to state what it represents.

A. Picture of froth taken through the side of the vessel magnified 225 times and the charge made up to contain four-tenths of 1% of pine tar oil. The froth extends beyond the top.

Q. 126. At the top?

A. At the top; yes, sir.

MR. SCOTT: I offer photograph 9-1.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 94.

Q. 127. MR. SCOTT: I hand you photograph 10-1. Please state what it represents.

A. Picture of froth taken through the side of the vessel magnified 225 times and the charge made up to contain one-half of 1% of pine tar oil; the froth extends beyond the picture.

MR. SCOTT: I offer picture 10-1.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT 95.

Q. 128. MR. SCOTT: I hand you photograph 11-1 and ask you what it represents.

A. Photograph taken through the side of the vessel magnified 225 times, the charge made up to contain six-tenths of 1% pine tar oil, and the froth extends beyond the picture at the top.

MR. SCOTT: I offer photograph 11-1.

John Warne Phillips.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 96.

Q. 129. I hand you photograph marked 12-1 and ask you what it is.

A. 12-1 is a photograph of froth taken through the side of the vessel magnified 225 times, the charge made up to contain 1% of pine tar oil. The froth extends beyond the picture.

MR. SCOTT: I offer photograph 12-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 97.

Q. 130. I hand you photograph 13-1. Please state what that is.

A. Photograph taken through the side of the vessel magnified 225 times, the charge made up to contain 1½% of pine tar oil. I think the froth extends to the top of the picture.

Q. 131. Looks as if it extended just about to the top, does it not?

A. Yes, to the top of the picture.

MR. SCOTT: I offer photograph 13-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 98.

Q. 132. I hand you photograph 14-1. Please state what that is.

A. 14-1 is a photograph of froth taken through the side of the vessel magnified 225 times, the charge made

John Warne Phillips.

up to contain 2% of pine tar oil and the froth extends beyond the picture at the top.

MR. SCOTT: I offer photograph 14-1

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 99.

MR. SCOTT: I hand you photograph marked 18-3 and ask you to state what it represents.

A. It represents a photograph of top view of froth, the charge made up to contain 25% kerosene oil.

Q. 133. The ore being the Butte & Superior as used in the other experiment?

A. No, the ore in this case was—yes, the ore in this case was the Butte & Superior ore, the same ore.

Q. 134. The acid and other elements the same as these photographs you have been testifying about?

A. All the conditions being the same except the quantity of oil and the kind of oil.

Q. 135. You said 25% kerosene?

A. 25% kerosene oil.

MR. SCOTT: I offer photograph 18-3.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 100.

Q. 136. I hand you photograph 18-2 and ask you to state what that represents.

A. 18-2 represents a side view of the same froth taken through the vessel magnified 25 times, the charge made up to contain 25% kerosene oil and the froth extends beyond the picture at the top.

John Warne Phillips.

Q. 137. Was it a voluminous froth?

A. Very voluminous froth.

MR. SCOTT: I offer photograph 18-2.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 101.

Q. 138. MR. SCOTT: I hand you photograph 18-1 and ask you what it represents.

A. 18-1 represents a photograph of the same froth taken through the sides of the vessel, magnified 225 times and the charge made up to contain 25% of kerosene oil and the froth extends beyond the picture at the top.

Q. 139. I notice in this picture shining spheres. Do you know whether they are oil globules or air bubbles, or what?

A. I think they are air bubbles in contact with the side of the glass and the particles are shoved over on the side.

Q. 140. The mineral particles?

A. The mineral particles.

Q. 141. So these are like air bubbles?

A. Yes.

Q. 142. Merely displaced froth?

A. Merely displaced foam that is in contact with the glass. I would like to state, with 225 magnification, that we get very little depth of the froth. We only get a picture practically of the plane through the froth and consequently when this is photographed right on the

John Warne Phillips.

froth it comes up against the sides of the vessel and we only get the froth right at that point, at the side of the vessel.

Q. 143. You don't get into the background at all?

A. Don't get into the background at all, because at that diameter or that magnification the froth beyond soon gets out of focus. Of course we get a little depth, but it soon gets out of focus beyond.

Q. 144. I would like to ask you if you notice in any of these other pictures with smaller quantities of oil shiny spheres similar to this.

A. I have, but not so plainly as in this one.

Q. 145. I wonder if you could pick out some there that show it, some with the smaller quantity of oil.

MR. SCOTT: I offer this photograph 18-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 102.

Whereupon an adjournment was taken until 2:00 o'clock p. m.

John Warne Phillips.

Tuesday, April 24th, 1917, 2:00 P. M.

JOHN WARNE PHILLIPS resumed the stand for further

DIRECT EXAMINATION.

BY MR: SCOTT:

Q. 146. I think that before recess I had asked you about the appearance of the shiny bubbles in the 25 per cent kerosene photograph, and asked you if you had noticed the same phenomenon in any of the froths with smaller amounts of oil, and I believe this is the one that you picked out to illustrate your answer with; what is that?

A. That is 17-1, exhibit 69.

Q. 147. You may describe again how much oil is used in the making of that froth?

A. It is made up of a charge containing three-tenths of one per cent of oil mixture No. 3, and has the same magnification as 18-1, 225 times.

Q. 148. We will find that kerosene picture; is that it, 18-1?

A. 18-1, yes, sir.

Q. 149. Exhibit No. 102?

A. Yes, sir.

Q. 150. You find the shiny bubbles in them both, one with three-tenths of one per cent of the mixture and the other with twenty-five per cent of kerosene?

A. Yes, sir.

John Warne Phillips.

Q. 151. Please show those to the court?

THE COURT: Those white specks you mean?

A. Yes, sir. You see these are the bubbles, and those white spots are from the reflection of the light.

THE COURT: Yes; that is what you are calling attention to?

MR. SCOTT: Yes, and the fact that it was in them with both quantities of oil.

Q. 152. MR. SCOTT: I hand you a photograph designated 15-2 and ask you to state what that represents?

A. This represents a photograph of froth, taken through the side of the vessel, magnified 25 times, the charge made up to contain two per cent of euca'yptus oil. The ore in this case was a mixture of chalcopyrite and silica.

Q. 153. Not a natural ore?

A. Not a natural ore, but a prepared sample, though, of course, both of these substances are natural in nature.

Q. 154. I understand. Does that froth extend to the top of the picture?

A. No.

Q. 155. Mark about where it goes to as near as you can discern?

A. About there.

MR. SCOTT: I offer this photograph 15-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 103.

John Warne Phillips.

Q. 156. I hand you photograph 19-2 and ask you to describe that?

A. 19-2 is a photograph of the froth taken through the side of the vessel, magnified 25 times, the charge made up to contain one-tenth of one per cent of eucalyptus oil. The ore used is B. & S. ore. I have marked the top of the froth.

Q. 157. Are these markings supposed to be exact, or approximate?

A. Approximate.

Q. 158. Just the same as looking at that jar?

A. Yes, sir.

MR. SCOTT: I offer 19-2 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 104.

Q. 159. I hand you photograph marked 20-2 and ask you to describe that?

A. This is a photograph of froth, taken through the side of the vessel, magnified 25 times, with a charge made up to contain one-half of one per cent eucalyptus oil, the ore being B. & S. ore.

Q. 160. Butte & Superior?

A. Butte & Superior.

MR. SCOTT: I offer this photograph in evidence, No. 20-2.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 105.

John Warne Phillips.

Q. 161. I show you photograph No. 15-1. Please describe it.

A. That is a photograph of froth taken through the side of the vessel, the charge made up to contain 2% of eucalyptus oil and the ore in this case was a mixture of chalcopyrite and silica; magnified 225 times; and the froth extends beyond the picture.

Q. 162. At the top?

A. At the top.

MR. SCOTT: I offer this photograph 15-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 106.

Q. 163. MR. SCOTT: I hand you photograph 19-1 and ask you to describe it.

A. Photograph of froth through the side of the vessel with a charge made up to contain one-tenth of 1% eucalyptus oil magnified 225 times. The froth extends to the top of the vessel.

MR. SCOTT: I offer photograph 19-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 107.

Q. 164. I hand you photograph marked 20-1 and ask you to describe it.

A. 20-1 is a photograph of froth through the side of the vessel magnified 225 times; charge made up to contain one-half of 1% of eucalyptus oil, the ore being Butte & Superior ore. The froth extends beyond the top of the vessel.

John Warne Phillips.

Q. 165. You notice in this picture the shiny spheres that I called your attention to in the other picture?

A. I do.

MR. SCOTT: I offer this photograph 20-1.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 108.

Q. 166. MR. SCOTT: I hand you photograph 19-3 and ask you to state what it is.

A. That is a top view of froth, the charge made up to contain one-tenth of 1% of eucalyptus oil.

Q. 167. What kind of a froth did that make?

A. It has a dead surface with a few bubbles on it, and not a very permanent froth, tender.

MR. SCOTT: I offer this photograph 19-3.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 109.

Q. 168. MR. SCOTT: I hand you photograph 20-3. Please describe it.

A. Top view of froth, the charge made up to contain one-half of one per cent. eucalyptus oil.

Q. 169. How does that froth compare with the one you last referred to?

A. That was one-tenth of one per cent of eucalyptus?

Q. 170. Yes.

A. This is much more permanent and much larger bubbles; shows a bubbly surface.

MR. SCOTT: I offer exhibit 20-3.

John Warne Phillips.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 110.

Q. 171. MR. SCOTT: Please describe photograph 27-1.

A. 27-1 is a photograph of froth made according to the California Technical Journal of November, 1903, but mechanically agitated.

Q. 172. In what sort of an agitator?

A. In this bar mixing agitator, the same as these other oils were agitated, and it had a magnification of 225 times and was taken through the side of the vessel; and the froth extended beyond the picture.

Q. 173. What was the ore that you used on this?

A. This is molybdenite ore.

Q. 174. And what quantity of oil?

A. The charge was made up of 15 grams molybdenite ore, 150 c.c. of water at 50° C., 2.4 c.c. smelter fuel oil equivalent to 2½ grams, and .4 c.c. sulphuric acid, and the agitation was 30 seconds.

MR. SCOTT: I offer photograph 27-1.

Said photograph was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 111.

Q. 175. I hand you this photograph—

MR. WILLIAMS: I think I ought to move to strike out the statement that it was made according to the California Journal of Technology because it appears on the face of it that it was not.

THE WITNESS: The charge is the same.

John Warne Phillips.

MR. WILLIAMS: I move to strike it out.

MR. SCOTT: It don't make any difference how it is on the record.

THE COURT: It may stand. The motion will be denied. If it varies the court will not attach any importance to it.

Q. 176. MR. SCOTT: I hand you photograph 27-3 and ask you to describe it.

A. 27-3 is a photograph of froth.

Q. 177. The same froth that was shown in 27-1?

A. 27-1, top view, and the charge is the same, of course.

Q. 178. You said it was the same froth?

A. Yes, sir.

MR. SCOTT: I offer this photograph 27-3.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT No. 112.

Q. 179. MR. SCOTT: Now, 27-2, photograph of what?

A. 27-2 is a photograph of the same froth.

Q. 180. Shown in 27-1?

A. Shown in 27-1 and 27-3, but taken through the side of the vessel and magnified 225 times.

Q. 181. Five diameters?

A. Five diameters.

Q. 182. The froth does not extend to the top of the mixture?

A. No, sir.

MR. SCOTT: I offer photograph 27-2.

John Warne Phillips.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 113.

Q. 183. MR. SCOTT: Please describe photograph 28-2.

A. 28-2 is a photograph of froth through the side of the vessel magnified five diameters and the froth extends beyond the photograph. This was made, this froth was made in accordance with the California Journal of Technology, Technical Journal, of November, 1903, and the agitation was by shaking. It is a picture of froth similar to that.

Q. 184. It is in a vessel similar to the one used for this court demonstration?

A. Yes, shaken in what they call a mixing bottle, hand shaken. The charge was made up to 50 grams of molybdenite, 150 c. c. of water, 2½ grams of smelter fuel oil and .4 c.c. sulphuric acid.

MR. SCOTT: I offer this photograph 28-2.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 114.

Q. 185. Did you mention the temperature?

A. 50° C.

Q. 186. I hand you photograph 28-1 and ask you to describe it?

A. 28-1 is a photograph of the same froth as 28-2, only the magnification is 225 times, instead of 25 times —15 diameters. The froth extends beyond the photograph.

John Warne Phillips.

MR. SCOTT: I offer in evidence photograph 28-1.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 115.

Q. 187. I hand you photograph No. 23 and ask you to describe fully the procedure resulting in that photograph there?

A. Photograph No. 23 is a photograph of bubbles taken from froth from a charge containing one-tenth of one per cent eucalyptus oil, Butte & Superior ore. The magnification is 20 diameters, or 400 times. These bubbles were separated from the froth, and placed in tubes containing clear water, and were photographed through those tubes.

Q. 188. Explain that a little more fully; I don't quite understand.

A. The bubbles were taken from the froth.

Q. 189. With a spoon or ladle or something?

A. With a glass tube put down in the froth and put your finger over the top and cut out a section of the froth, and that tube was put down in a basin of clear water again and the tube bent over sideways so as not to allow the clear water to enter the tube, and any bubbles that were broken, the sediment would fall to the bottom; then I took another tube of clear water and transferred some bubbles from that tube, under water, into this second tube, in order to get clear water. Small corks were put in the end of that tube, and it was taken out and photographed.

Q. 190. And these bubbles were inside of that tube?

John Warne Phillips.

A. Inside of the tube. You can sort of see the line of light of the tube, that line on the photograph.

Q. 191. And this other line, is that also the tube?

A. No, that is a sort of reflection of the side of the tube.

Q. 192. Everything we see here is inside the tube?

A. Everything is inside the tube.

MR. SCOTT: I offer this photograph No. 23 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 116.

Q. 193. Please describe photograph No. 24?

A. No. 24 is a photograph of bubbles made the same as photograph 23. The magnification is the same, 400 times, and the bubbles were taken from froth made from a charge containing one-half of one per cent of eucalyptus oil.

MR. SCOTT: I offer photograph 24 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT No. 117.

Q. 194. Please describe photograph No. 25?

A. Photograph 25 is a photograph of bubbles made in the same way, the magnification 400 times. The bubbles were taken from froth from a charge containing one-tenth of one per cent oil mixture #3.

MR. SCOTT: I offer photograph 25 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 118.

John Warne Phillips.

Q. 195. Photograph 26, please state what that is?

A. It is a photograph of bubbles made in the same way as the preceding; magnification 400 times. The bubbles were taken from a charge containing one-half of one per cent of oil mixture #3.

Q. 196. This is the same oil mixture #3 that you previously referred to?

A. Yes, sir.

Q. 197. And the procedure here was the same as in these other pictures of bubbles?

A. The same.

MR. SCOTT: I offer photograph 26 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 119.

MR. WILLIAMS: Did you state what the ore was in these last four?

THE WITNESS: Butte & Superior ore, in all those bubbles.

Q. 198. MR. SCOTT: I hand you photograph 29.

A. It is a photograph of bubbles made in the same way, but the magnification is 256 times; 16 diameters. The bubbles are taken from froth from a charge containing one and a half per cent of oil mixture. That is not oil mixture #3.

Q. 199. That is not #3, but the other oil mixture you described?

A. Yes, sir.

MR. SCOTT: I offer photograph 29 in evidence.

John Warne Phillips.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 120.

Q. 200. And the ore?

A. Butte & Superior.

Q. 201. I hand you photograph No. 30. Please describe it?

A. Photograph of bubbles made as in the preceding photograph. The magnification is 576 times, 24 diameters.

Q. 202. The oil?

A. The quantity of oil was one and a half per cent oil mixture; Butte & Superior ore.

MR. SCOTT: I offer photograph 30 in evidence.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 121.

Q. 203. I hand you photograph No. 31; please describe it?

A. Photograph 31, photograph of bubbles made as in the preceding; magnification of 576 times. The bubble was taken from froth from a charge containing two per cent eucalyptus oil, and the ore used was a mixture of silica and copper pyrite.

MR. SCOTT: I offer in evidence photograph No. 31.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT 122.

Q. 204. Please describe photograph No. 32?

John Warne Phillips.

A. No. 32 is photograph of bubbles made as in the preceding; magnification 576 times. Bubble taken from a charge containing two per cent eucalyptus oil. The ore used was a mixture of silica and copper pyrite.

MR. SCOTT: I offer photograph No. 32 in evidence.

Photograph admitted in evidence and marked DEFENDANT'S EXHIBIT 123.

Q. 205. I take it that this photograph represents the apparatus used for making these froths?

A. Yes, that is the apparatus used in making these froths or most of them.

MR. SCOTT: I offer this photograph last referred to by the witness.

Said photograph was admitted in evidence marked DEFENDANT'S EXHIBIT 124.

Q. 206. Now, in making these froths represented in these photographs, were a large number of each individual photograph made for the purpose of selecting or did you go right ahead from one to another, take them, we might say, as they came?

A. We repeated no froth except in the smaller percentages of oil, like one-tenth of 1%.

Q. 207. Are those the two that you referred to as being rather thin and meager?

A. Yes. I think these froths were repeated about three times; but in all others we went straight ahead and in no other case was a froth repeated.

John Warne Phillips.

Q. 208. Simply photographed the first one you made with each quantity, with that exception?

A. Photographed the first one we made.

Q. 209. Now, if it wouldn't take too long, I think it would be good to state approximately the thickness of these different froths. You can designate them by your own symbols, that appear on the photographs.

MR. WILLIAMS: You mean the height?

MR. SCOTT: Thickness of the froth.

MR. WILLIAMS: The height, is that what you mean by the term "thickness"?

MR. SCOTT: It may be that your selection of language is more accurate. I think of it as "thickness". If more pleasing to you we will change the form of the question to "height."

A. I have the thickness of most of the froths and those that I didn't take, of course I omitted, but I thought the photographs themselves would speak for the depth of the froth, but I have most of them. Photograph marked No. 16—

Q. 210. That would apply to 16-1, 16-2 and 16-3, all?

A. Yes, 16-1 and 16-2 and 16-3. The froth of test 16 in the photographs 16-1, and -2 and -3, was one quarter of an inch thick. The froth from test No. 17, as indicated in the photographs 17-1, 17-2 and 17-3, the froth was one-half inch thick. In test No. 1, I have no measurement of the froth. Test No. 2, represented by photographs 1, 2, and 3, the froth was 11-16 inches thick. In test No. 3, represented by photo-

John Warne Phillips.

graphs 1, 2 and 3, the froth was three-quarters of an inch thick. In test No. 4, representing photographs 4-1, 4-2, and 4-3, the froth was  $13/16$  of an inch thick. In test No. 5, representing 5-1, 5-2 and 5-3, the froth was  $11/16$  of an inch thick. In test No. 8, representing photographs 8-1, 8-2 and 8-3, the froth was  $11/16$  inches thick. In test No. 9, representing photographs 1, 2 and 3, the froth was  $3/8$  of an inch thick, very large bubbles. In test No. 10, representing photographs 10-1, -2 and -3, the froth was  $7/16$  inches thick.

In test No. 11, representing photographs 1, 2 and 3, the froth was  $6/16$  or  $3/8$  inches thick. In test No. 12, representing photographs 12-1, 12-2 and 12-3, the froth was one-half inch thick. In test No. 13, representing photographs 13-1, -2 and -3, the froth was  $6/16$  inches thick.

MR. WILLIAMS: Three-eighths?

A. Three-eighths. In test No. 14, representing photographs 1, 2 and 3, the froth was  $3/8$  inches thick. Test No. 15, representing 15-1, 15-2, the froth was three-quarters of an inch thick. Test No. 16, representing photographs 16-1, -2 and -3, the froth was  $1\frac{1}{4}$  inches thick. Test 17, representing photographs 17-1, -2 and -3, the froth was  $\frac{1}{2}$  inch thick. Test No. 18, representing photographs No. 18-1, 18-2 and 18-3 the froth was an inch and a quarter thick. Test No. 19, representing photographs 19-1, 19-2 and 19-3 the froth was  $5/16$  of an inch thick. In test No. 20, representing photographs 20-1, 20-2 and 20-3, the froth was one-half inch thick. Test No. 21, representing photograph

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21-1, 21-2 and 21-3, the froth was  $1\frac{1}{4}$  inches thick. In test No. 22, representing 22-1, 22-2 and 22-3, the froth was  $5/8$  inches thick. That is all of them.

Q. 211. In making these photographs have you any recollection or record of about the length of time that elapsed after the froth formed and before the photographic plate was exposed, that is, the intervening time between the formation of the froth and the exposure of the plate?

A. I have.

Q. 212. I don't know that it is necessary to go into detail for each picture, but I would like to know, in a general way, the average.

A. Here is test No. 2. The test—After stirring up the mixture we let it settle for about five minutes, then we took plate No. 2-1. Say this was 1.30. At 1.30 in the afternoon we took plate No. 2-1 and in that case we took two pictures, two plates of No. 2-1. The first was not long enough exposed. And then at 1.53 we took 2-2, and at 2.07 we took 2-3, so these photographs were taken in that order just as soon as practicable, we took them. First the froth is formed and allowed to stand from three to five minutes and then the photographs were taken, and were taken of course, 1, 2 and 3, as soon as possible with a certain interval, sometimes 5 minutes between the plates, sometimes 10, but never over 15. So the time lapsing between the forming of the froth and the last photograph would be less than an hour.

Q. 213. Somewhere near an hour possibly?

John Warne Phillips.

A. Somewhere near an hour. But less than an hour.

Q. 214. Can you repeat a few typical instances of this, illustrate here in court with the apparatus you used?

A. I think I could.

MR. SCOTT: If the court will indulge me a moment while we get the table in and the little bar mixer, we will show a few instances and if the other side desires any particular one of these that were performed we will be pleased to select the one they want. Otherwise we will pick out a few ourselves.

THE COURT: Where have you your supplies?

MR. SCOTT: They are right upstairs in a room, and they have been told and they are all ready to carry them right in.

THE COURT: Very well, have them brought down promptly.

Q. 215. MR. SCOTT: What experiment do you propose to perform?

Test No. 3.

A. Take four-tenths.

Q. 216. Of what?

A. The oil mixture.

Q. 217. With what ore?

A. Butte & Superior ore. We have a 60 gm. charge.

Q. 218. Now, Mr. Phillips, if you will describe the charge that you have placed in the jar?

A. The charge is made up of 60 gms. of Butte & Superior ore, and of 250 c.c. of water at about 75° F.;

John Warne Phillips.

also 2 drops of copper sulphate solution, which is equivalent to one-tenth of one pound of copper per ton of ore, and sulphuric acid was added equivalent to eight pounds of 60° Be. acid per ton of ore. I will now agitate the pulp before the addition of the oil for half a minute, so as to thoroughly mix the pulp through the water, which gives natural conditions.

(Witness turned on electric motor with small impeller attached.)

Q. 219. MR. WILLIAMS: At what rate of speed — how many revolutions does that impeller run?

A. I think it is run near 1,800, but I don't know.

Q. 220. MR. SCOTT: You may proceed, Mr. Phillips, and you may investigate that afterwards for Mr. Williams.

A. Now, in making a one-tenth of one per cent oil charge, it requires three drops of oil, so that four-tenths of one per cent would require 12 drops of oil. I will now agitate the charge again.

Q. 221. How long are you going to agitate the mixture?

A. I am going to agitate it eight minutes, which was the time I agitated the mixtures for the photographs.

Q. 222. Is it necessary to agitate it that long, do you think?

A. No, in some cases it is not.

Q. 223. You did that merely for uniformity, I suppose?

A. For uniformity. Any time between five and ten minutes, or sometimes less would do, but I did that for uniformity.

John Warne Phillips.

A. Eight minutes agitation.

Q. 224. Now, Mr. Phillips, when that settles a little bit I would like to have you show it to the court. Have you an extra jar, Mr. Phillips, so we can keep that one while we make one with a larger quantity?

A. I have, yes sir.

Q. 225. Now, if you will go right ahead, Mr. Phillips.

A. In making another one—

Q. 226. (Interrupting.) I think the largest of this series was  $1\frac{1}{2}\%$  of the oil mixture, that is, photographs 5-1, 5-2 and 5-3?

MR. WILLIAMS: 1.5.

Q. MR. SCOTT: 1.5% of the same oil mixture, that being .4 of a per cent that you have just made.

(The witness performs the experiment.)

Q. 227. That corresponds, does it, to photographs 5-1, 5-2 and 5-3?

A. Yes, sir.

Q. 228. I mean the charge?

A. This charge corresponds to photographs 5-1, 5-2 and 5-3, contains 60 grams of ore, 250 c.c. of water, about 75° F., and sulphuric acid equivalent to 8 lbs. of 60° Be. acid to a ton of ore, and copper sulphate equivalent to one-tenth of one pound of copper per ton of ore. Agitated one-half minute before the oil was added and then added oil No. 3, 42 drops of oil mixture, No. 3, which is equivalent to  $1\frac{1}{2}\%$  of the ore added, and the amount of oil which is equivalent to

John Warne Phillips.

one-tenth of 1% of the ore added. Instead of being exactly 3 drops was 2.8 drops by calculation in letting a large number of drops flow, so that makes—that 42 drops of oil equivalent to 1½% instead of 45 drops as would be in the other case. We agitated it eight minutes.

MR. SCOTT: If there are any details you wanted, I would rather you would ask them and have them put on the record, Mr. Williams.

THE COURT: Any of the aides of any of you that desire to examine this of course can step up to the edge and do so.

MR. SCOTT: Mr. Phillips, now for just one more of these, can you reproduce one, I think No. 18, with 25% of kerosene?

A. I think so, yes, sir.

Q. 229. 18-1, 18-2 and 18-3 are of a froth made with 25% of kerosene.

A. Yes, sir.

Q. 230. You haven't another one of those jars have you?

A. No, we will have to clean one of these jars.

MR. SCOTT: After everyone has examined that we can throw one of those out.

Q. 231. Referring to this last demonstration, Mr. Phillips, with 1½% of that oil mixture, I understood you to say before that you adopted a uniform period of agitation of about eight minutes?

A. Yes, sir.

Q. 232. You did that simply for the purpose of comparison of the different froths?

John Warne Phillips.

A. Yes.

Q. 233. Would you regard this one that you have just made as requiring that long agitation to make a froth?

A. I should not.

Q. 234. If it had been your aim to carry out the operation most efficiently would you have adhered to that eight minutes?

A. I would not.

Q. 235. You wanted to explain something about the oil mixture. In these photographs it is oil mixture, the second one you described?

A. Yes.

Q. 236. Not the No: 3, but the other one.

A. Not No. 3. And in this experiment only No. 3 was used.

Q. 237. That was because it was available or why?

A. That was because the other oil mixture was not available.

MR. SCOTT: Will you empty one of those jars?

MR. WILLIAMS: Empty the one with the 1½%. We would like to keep the one with the four-tenths per cent, although we would like to keep them both.

MR. SCOTT: Take the 25% of kerosene test, No. 18, that will be all I will ask you to do.

Q. 238. Is this the same apparatus that you used in the test for the photographs?

A. This is the same apparatus that we used for a part of them and the other part I used an apparatus similar to that, but it is in Chicago.

John Warne Phillips.

MR. WILLIAMS: While we are waiting, have you any accurate data which will enable you to tell us the speed of rotation of that impeller when it is in operation?

MR. SCOTT: Is it marked on the machine, Mr. Phillips? Sometimes they are.

MR. PHILLIPS: No, it does not give the speed.

MR. SCOTT: And the diameter of the impeller is about three-quarters of an inch; is that right?

A. It is.

Q. 239. Is this going to be eight minutes, too?

A. No, a half minute now to mix it up.

Q. 240. But finally, I mean?

A. Agitated four minutes, the same as the last, the one in the photograph.

Q. 241. Make it the same then, four minutes.

Q. 242. You may describe the charge you have put in the jar?

A. 60 gms. of Butte & Superior ore, 250 c. c. of water, copper sulphate equivalent to one-tenth of a pound of copper per ton of ore; sulphuric acid equivalent to eight pounds of 60° Be. acid per ton of ore; and 25 per cent of kerosene.

Q. 243. Reckoned on the weight of the ore?

A. Reckoned on the weight of the ore. The kerosene is of the specific gravity of .815, which would be equivalent to 18.4 cubic centimeters of oil. We will agitate this four minutes, as I have a record of four minutes for this mixture.

MR. WILLIAMS: Do you know the Baume measurement of that kerosene?

John Warne Phillips.

A. No, I do not.

(Agitating machine was run for four minutes.)

MR. WILLIAMS: On behalf of the plaintiff I would like to test that apparatus that he used in court.

MR. SCOTT: For speed, you mean?

MR. WILLIAMS: We would like to do some of these things with it.

MR. SCOTT: All right.

Q. 244. Do you find, Mr. Phillips, that this 25 per cent of kerosene froth is made up of bubbles or not?

A. I do; I find it is made up of bubbles.

Q. 245. How about the one you made with one and a half per cent—that is gone, but you remember it I guess. This one is the four-tenths of one per cent.

A. I think it was made up of bubbles also.

#### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 246. In the three experiments you did in court you added sulphate of copper, was it?

A. I did.

X-Q. 247. Did you do that in all the other experiments?

A. All the other experiments.

X-Q. 248. So that every experiment that you have described here, in addition to what you described in your testimony, you used sulphate of copper?

A. I think I did. I think I outlined my charge at the first and all these experiments were made prac-

John Warne Phillips.

tically on the same charge with the exception of the quantity of oil changing and the variety of oil, that the charge was 60 grams of ore, 250 c. c. of water and enough copper sulphate to be equivalent to one-tenth of one pound of copper per ton of ore, and enough sulphuric acid to be equivalent to 8 pounds of 60° Be. sulphuric acid per ton of ore, and then I agitated that mixture for one-half a minute so as to thoroughly moisten the pulp so that we would have the condition in the test as would prevail in the mill, and then added the oil and proceeded to the agitation from the addition of the oil, not taking into account the half minute used in stirring up the pulp in the time of agitation.

X-Q. 249. And in all these operations did you put the stirrer down to the bottom of the jar as you did those that were done in court?

A. I did. I operated the apparatus as I thought it was constructed to be operated. That is automatic, when you shove it down it makes contact; when you draw it up it disconnects.

X-Q. 250. So that when the impeller enters the pulp it is rotating at its maximum speed and when it left the pulp it was rotating at its practically maximum speed?

A. I wouldn't say "maximum speed," but it was rotating on entering the pulp and on leaving the pulp.

X-Q. 251. That is, the apparatus is so arranged that, as you push it down it commences and starts up?

A. It starts up.

X-Q. 252. And as you lift it up it disconnects at some point?

John Warne Phillips.

A. It does. Supposed to be automatic in action.

X-Q. 253. That, of course, having been designed for the purpose of facilitating the mixing of drinks?

A. Yes, sir, it was.

X-Q. 254. And the ores that you used today, what was that ore? You just described it as Butte & Superior, but you didn't speak anything of its condition.

A. Butte & Superior, it was mill run No. 2. It contains 16% of zinc and 6% on an 80 mesh screen and 60% through a 200 mesh.

X-Q. 255. And is it ore that has been through the water concentration process and the tailings of that process or is it a raw ore ground up?

A. I really can't answer on that. I do not know. Mill run No. 2—I don't know.

X-Q. 256. You don't know it except by that name?

A. I know it by that name and I know it by that composition.

X-Q. 257. Now, in several of these experiments you used something which you said was labeled "wood tar oil" and in others you have used something that was labeled "pine tar oil." What knowledge have you as to the oil itself?

A. I just took the—practically had no knowledge as to the composition of the oil itself. I didn't test the oil as to its composition, but I understood that in this case the wood tar oil and the pine tar oil are very nearly the same.

X-Q. 258. What is the basis of that understanding?

John Warne Phillips.

A. I think it would be some—I can't answer.

X-Q. 259. Well, were you so informed?

A. I was so informed, and the odor, etc., would so indicate it.

X-Q. 260. And who informed you?

A. It was sent to us in Chicago from the Butte & Superior Mining Company and the can was labeled "Pine Tar Oil."

X-Q. 261. And the other one, the wood tar oil?

A. By the way, I have a sample of these oils, both the pine tar and the oil mixture.

X-Q. 262. Let us have a specimen of each. Have you the oils that you used in these photographs? We already have had specimens of what you used in court. Will you let us have specimens of the other?

A. I can.

X-Q. 263. As soon as your deposition is completed please hand them to Mr. Higgins. And this eucalyptus oil, where did that come from?

A. I purchased it at a drug store here in Butte.

X-Q. 263½. And how was it designated?

A. Eucalyptus oil. They said it was California oil and it had a specific gravity of .925.

X-Q. 264. And you have a specimen of that, of course?

A. I have a specimen of that.

X-Q. 265. Do you know whether it was Eucalyptus Amygdalina?

A. I do not. They said it was California eucalyptus and not the Australian.

John Warne Phillips.

X-Q. 266. Now, you had a made-up ore of calcopyrite and silica, can you let us have a specimen of that?

A. I can not, no sir.

X-Q. 267. You did not give us a composition of that ore?

A. I just made that up for my personal experiment is all. It was made up of a very nearly pure chalcopyrite ground fine and just mixed with pure fine ground silica, about 6% each, and that was only made in a small quantity and I have no sample of that.

X-Q. 268. Chalcopyrite is, of course, sulphide of copper?

A. Yes.

X-Q. 269. And that is a metalliferous mineral?

A. Yes.

X-Q. 270. And silica is one of the usual gangue?

A. One of the usual gangue.

X-Q. 271. Now, the magnification which characterized your photographs numbered 1 and 2, were 15 diameters and five diameters?

A. Yes.

X-Q. 272. Now, you would characterize that as enlarged 15 times and enlarged 5 times, wouldn't you, in the ordinary course of events?

A. No, sir. That would be enlarged—the diameter of the enlargement would be according to the square of the diameters on account of the area, having two dimensions.

X-Q. 273. That is to say, comparing one man three feet high and another six feet high, the man six feet

John Warne Phillips.

high would be four times as large as the man three feet high; is that right?

A. I would rather take another illustration, if I may. If you measure one side of this table as two feet, if the table is two feet square and you add two feet more on the side of the table, that table has 16 square feet, don't you see, instead of four. That is the area of the surface. So the magnification in that way increases it two diameters, which makes the area four times as big, which is the square of two. And so the magnification in this case would be the square of 15 and the square of 5.

X-Q. 274. Well, if you had a mechanical drawing and you made all the dimensions one-half you would call it "half size," wouldn't you?

A. Call it half size.

X-Q. 275. And then it would be one-fourth the area? Is that right?

A. It would be one-fourth area.

X-Q. 276. The fact is that the dimensions were only magnified 15 and 5 times, the dimensions?

A. I hadn't thought about the other. In making drawings we are dealing with lines which only have one dimension, and when you make it half size you make the line half as long, you see, and this is making a line half size, and you divide the area by one-quarter. so one-half an inch has only one-quarter of the area that an inch has.

X-Q. 277. I think that that is sufficiently clear, but as a matter of fact all of the dimensions in that number one are increased fifteen times?

John Warne Phillips.

A. All the linear dimensions, yes, but the areas are increased 225 times.

X-Q. 278. And all linear dimensions in the others are increased five times, although the dimensions are increased 25 times, the square of five?

A. Yes, sir.

X-Q. 279. I suppose you did this work under the direction of some one?

A. Well, no, sir, I did the work myself. I made all the tests and measurements as I did here, and I had the photographer right there with me, and he made the photographs under my direction, and I marked the plates in the dark room as soon as they were exposed, and he developed them and did the printing.

X-Q. 280. I thought you said <sup>me</sup> Dr. Dosenbach helped you?

A. No, sir; I don't remember saying so.

X-Q. 281. Who laid out the plan of operation for you?

A. Mr. Hoskins and I together talked over the plans.

X-Q. 282. You received the plans, did you?

A. I suppose Mr. Hoskins did—as I understand it, I think the idea is Mr. Hoskins'. He did not receive any plans of these tests at all.

X-Q. 283. As far as you know you did them along the line of Mr. Hoskins' plan?

A. Yes, sir.

X-Q. 284. What was the highest percentage that you used of the wood tar oil or the pine tar oil?

John Warne Phillips.

A. I think two per cent.

X-Q. 285. And the highest percentage you used of those oil mixtures?

A. One and a half per cent.

X-Q. 286. Where did you get the kerosene from that you used in your experiments?

A. I got it upstairs in the laboratory in a bottle.

X-Q. 287. I mean when you photographed?

A. At the same place.

X-Q. 288. It was sent to you?

A. No, sir, it was in the laboratory in this building, upstairs.

X-Q. 289. When you made the photographs?

A. Yes, sir.

X-Q. 290. Were the photographs made in this building?

A. Some of them. I think it is the same kerosene that I used in the experiment here—out of the same bottle.

X-Q. 291. This is the kerosene that was in the laboratory of the defendant; it was in the laboratory of the defendant that you got it?

A. In this laboratory in this building, yes; but whether it was in their other laboratory I don't know.

MR. WILLIAMS: That is all, unless, after testing the apparatus we find that we may want to ask a few more questions for further enlightenment.

Frank R. Wicks.

RE-DIRECT EXAMINATION,

BY MR. SCOTT:

R-Q. 292. Do you think, Mr. Phillips, that it makes any difference whether this agitation ~~or~~ <sup>are</sup> is running at the moment it enters the pulp and at the moment it leaves the pulp?

A. I don't think it does; I think it makes no difference.

R-Q. 293. If you requested to, are you willing to repeat these experiments and stop the agitator before it leaves the pulp and not start it until after it enters the pulp?

A. I am.

WITNESS EXCUSED.

FRANK R. WICKS, recalled, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Mr. Wicks, you have informed me that there were some errors in the tabulation which you produced and which is in evidence as exhibit 28, "Chino Copper Company, record of flotation operations for the treatment of slime vanner tailings."

A. Yes, sir.

Q. 2. You may state what these errors are, but before you do that and give the corrections, you may explain how they occurred?

Frank R. Wicks.

A. The errors were made by the clerical department in making up the statement, and they were not discovered until after we checked them over here, so that we went through and re-compiled the entire statement. I did that personally.

Q. 3. You had the figures to make the corrections from?

A. Yes; we brought them with us.

Q. 4. What was the nature of the first error that you refer to?

A. The first error here is in the first column, under "weight, dry tons"; the figure on the fourth line, 8065, was added in the total twice, so that that changes the total of that column by the amount of 8065.

Q. 5. What is the correct total then?

A. 2,064,070 is the correct total.

Q. 6. And the next particular in which there is an erroneous statement here?

A. In the next column, under the heading of "average daily tonnage" we made one or two changes; for instance, the first figure was given as 410, and we figured 573.

Q. 7. What did you figure that from?

A. The number of days shown there, 15 days, and the total weight treated during the time was 8600 tons.

Q. 8. It was simply a question of division?

A. Yes, sir.

Q. 9. What next?

A. Do you wish me to enumerate each of the changes as I go down?

Frank R. Wicks.

Q. 10. You can do it in the way that is most convenient for you?

A. There were a great many of these figures that did not enter into the original record; will it be necessary to repeat each one of them?

Q. 11. Well, you can state what the corrections are in the exhibits?

A. In the same column, the fourth line, 979 should be 1251.

Q. 12. How did that error occur?

A. In the same manner; it was an error in taking the number of days.

Q. 13. An error in computation?

A. Yes, sir. The average daily tonnage shown for the year 1915, reported as 1179, should have been 1812. All of these errors occur in taking the wrong number of days to figure against; they are really immaterial. 3,048 shown for the second quarter of 1916 should have been 3,081; and the average of our operations to date, as shown at the bottom of that column, 2999, should have been 3127.

Q. 14. The difference in the average arising from the change in the figures you have mentioned?

A. Yes, sir. Now, the next column "assay per cent copper." When we were making the corrections we thought best to change the averages from ordinary numerical averages to calculated averages, because the calculated averages are more nearly accurate.

Q. 15. Explain the difference between them?

Frank R. Wicks.

A. For instance, the average of any one quarter or for one year, or for any actual part of the time, sometimes it is accurate enough if we arrive at the average arithmetically, if we simply add up the column and divide by the number of items. But that is not always quite accurate, because, for instance, we might have 100 tons of two per cent ore and ten tons of one per cent ore, so we could not very well add up the one per cent and the two per cent and take a numerical average of one and a half per cent, but we can take the calculated average, taking into consideration the totals, which is more accurate.

Q. 16. And you changed that column in the assay per cent of copper in the manner you have indicated?

A. Yes, sir.

Q. 17. Does it change the average?

A. No, sir; it changes the average for 1915, which was shown as .798, and it is now changed to .78. In the first quarter of 1916, which is the figure following that, .88 is changed to .89. The third quarter of 1916, .86 is changed to .82, and the average for the year 1916 is changed from .84 to .83, and the average for the first quarter of 1917, the last figure in the column, is changed from .75 to .74. The average of the entire column is changed from .814 to .804.

Now, Mr. Williams has called attention to certain errors in the tonnage in the first column, which is headed "flotation concentrates, weight, dry tons." I find that in making that up that in some way they got the tonnage of the rough concentrate during that period,

Frank R. Wicks.

instead of the tonnage of the finished concentrate—or at least during a portion of the period, so that we are changing the total tonnage for the fourth quarter of 1915 from 20,842 to 2,874. The figure following that, which depends on that, is changed from 23,285 to 4,889; and the next figures, 3915 is changed to 2952, which applies to the first quarter of 1916. The figure shown for the fourth quarter of 1915, 3668 is changed to 3676. Of course the year is changed from 13,945 to 12,990, and the total of the column is changed from 41062 to 21713.

Now, in the next column we made a few minor changes, not particularly important, but I will enumerate them. For the period July 13th to 23rd, inclusive, the figure shown as the assay per cent copper of flotation concentrate 4.90, is changed to 4.23. The third quarter average is changed from 16.93 to 16.99. Those averages are being changed, as I said, because of using the geometrical or calculated averages instead of the arithmetical averages. The first figure of the fourth quarter is changed from 23.08 to 23.43; the next figure is changed from 22.06 to 19.95.

A. For the first quarter of 1916, 21.27 is changed to 21.13. The next figure, 27.03 to 27.35. The next one, 28.07 to 29.64. The next one, 29.53 is changed to 29.64. The average for the year 1916 is changed from 26.48 to 26.47. The last figure in the column, which is the average for the first quarter of 1917, is changed from 28.63 to 28.47 and the average for the

Frank R. Wicks.

entire column is changed from 24.175 to 25.352. You will notice that there are no changes in the dates in which the special ones were made because that was not effected. Flotation tailings, assay per cent. copper for the third quarter is changed from .47 to .48. The next figure from .54 to .56, and the next figure from .54 to .56 which is the same. The next one, .67 is changed to .68. The average for the column is changed from .539 to .543. Now, there was just one more column, "Flotation tailings per cent. indicated recovery." The average recovery for May 1 to 25 is given as 23.01, is changed to 21.40. For the period July 13 to 23, 30.37 is changed to 30.73. The next figure, 35.35 is changed to 34.88. The next one from 35.72 is changed to 28.81, and the average for the year 1915 is changed from 33.14 to 29.32. The first quarter of 1916 is changed from 25.92 to 24.25. The next one, 33.43, changed to 34.36. The next one, 35.94 to 35.68. The next one, 37.59 is changed to 37.39, and the average for the year 1916 is changed from 33.27 to 33.05. The average for the first quarter of 1917 is changed from 37.87 to 37.84, and the average of the column is changed from ~~34.553~~ to 33.139. Just one other little change in the quality of oil used during the year 1915 given as 1.04 pounds per ton, is changed to 1.06 pounds per ton. I believe that covers all the changes made.

Q. 18. These changes in the column~~s~~ headed "Percentage of Indicated Recovery," how did they arise?

Frank R. Wicks.

A. Those are also due to the changing from the arithmetical to the calculated average.

Q. 19. And the errors that you pointed out in the column "Assay Per Cent. Copper"?

A. Of flotation tailings?

Q. 20. Yes.

A. The same is true of that.

Q. 21. The change from the arithmetical to the calculated average?

A. Yes, sir.

Q. 22. I think Mr. Williams asked you when you were on the stand before to compile for April 4, the total amount of oil percentage, or the total amount of oil relative to the total tonnage that was in the ore including both circulating and original oil, and ore. That was my understanding of his question?

A. Yes. I have my figures here on that. I will read them. They will afford an explanation of the manner in which that is compiled. The dry tons of initial feed treated during that 24 hour run on April 4th was 3250 as is shown on this statement. The measurements of the circulating load show 8053 wet tons of material circulating in the 24 hours. The solids in that circulating load were found to be 6.23%. You will remember that I gave you a figure of 6.00 and 6.5% copper for the average of the two taking into consideration the difference in tonnage, figures to be 6.23%. They therefore calculate that there were 502 dry tons in the circulating load. This amount, added to the initial feed would be 3782 tons, dry tons

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of total feed in the plant. We added a total amount of oil of 26330 pounds. This is equivalent to 8.1 pounds on the initial feed. Or, if it is figured, the total feed would be equivalent to 7.0 pounds per ton.

Now, the total pounds of oil circulating, which is determined by analyzing the wet circulating load, was 10495 pounds of oil circulating during the 24 hours. That circulating oil is equivalent to 3.20 pounds per ton of initial feed, or it is equivalent to 20.0 pounds per ton of the circulating feed, or figured ~~against~~ <sup>against</sup> total feed, that is ~~is~~ <sup>is</sup> 113 pounds and the

P. 2938, L. 14, insert "of initial feed is 113 pounds and the  
total oil," after "ton"

~~that statement~~  
~~can be taken one way or another. The headings~~  
can be taken one way or another. The headings are not particularly lengthy and it might possibly lead to some confusion; but with that statement that ought to make it clear.

Q. 23. Taking into account, Mr. Wicks, the circulating oil with the amount stated of initial oil pounds per ton for March 13, 14, 21 and 27, represents more ore than the total amount of oil of all kinds per ton of material in the machine, of all kinds, both circulating and original?

A. Well, if we figure the total oil against the total feed on those days I am quite positive that the pounds of total oil per ton of total feed would have been considerably greater than that, because we find that the amount of oil in the circulating load per ton of the material in the circulating load is equivalent to two and

Frank R. Wicks.

a half times the figures which would represent the initial oil, per initial ton. That is a little hard to figure, but if it is not clear, I can explain it further.

Q. 24. You mean that the middlings carry a considerably greater proportion of oil than is actually supplied to the initial feed?

A. Yes, sir. That ratio that we have established from what tests we have made would apply, for example on the 13th of March, on which day we had 24 pounds of initial oil per ton of actual feed; we would have, for every ton of circulating load on that day, we would have from 48 to 60 pounds of oil per ton of circulating feed. Do you see?

Q. 25. In other words, the circulating feed carried more oil than is supplied to the original feed?

A. Yes, sir.

Q. 26. And that excess brings the total average up?

A. Yes, sir.

Q. 27. I think you were asked when on the stand before to give some information as to the operations on November 18th, 19th and 20th of 1916, which are set forth on exhibit 26, "Chino Copper Company, Record of Flotation Operations and Retreatment of Vanner Concentrates"?

A. Yes, sir, I have some figures here on that. On November 18th, 19th and 20th Mr. Williams asked me to give him the exact percentages of different kinds of oil used on those days. Now, the original records show that on November 18th we used 3985 pounds of Barrett's No. 4 creosote and 225 pounds of Jones oil,

Frank R. Wicks.

no other oil was used. On November 19th, we used 4025 pounds of Barrett's No. 4 creosote and 200 pounds of Jones oil, and no other oil was used. On November 20th we used 4500 pounds of Barrett's No. 4 creosote and 330 pounds of Jones oil. You also asked me in connection with that to give you the percentage of the oils used on the 25th of November, which was a day during which we used 26.14 pounds of oil per ton of initial feed. On that day we used 4570 pounds of Barrett's No. 4 creosote and 240 pounds of Jones oil. On the 18th, 19th and 25th the proportion was approximately 95% of the Barrett's No. 4 creosote and 5% of the Jones oil. On the 20th the proportion was 93% of Barrett's and 7% of Jones.

Q. 28. Did you state how the errors arose in the column "Flotation Concentrate Weights, Dry Tons" in this exhibit 28?

A. Yes, sir. In making that up, they included a tonnage of rough concentrate instead of a tonnage of finished concentrate.

Q. 29. Have you a corrected table embodying these corrections which you have pointed out?

A. Yes, sir.

Q. 30. Of which you have extra copies?

A. Yes, sir. I would say that Mr. Wiser and I compiled this statement, each of us performing practically all of the operations in order that we would both satisfy ourselves that it was correct, but Mr. Wiser signed the statements because he signed the first copy or the original statement.

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Q. 31. The one that was put in evidence before?

A. Yes, sir.

Q. 32. But you have calculated these corrections from original data, I understand?

A. Yes, sir.

MR. SCOTT: Then I will offer this corrected statement. Any objections?

MR. GARRISON: The same objection; our standing objection only.

The statement was admitted in evidence and marked DEFENDANT'S EXHIBIT 125.

MR. SCOTT: That will be all. Have you any cross examination?

MR. WILLIAMS: Just one or two questions.

CROSS EXAMINATION,

BY MR. WILLIAMS:

X-Q. 33. Mr. Wicks, in your table of "Flotation Operations on Retreatment of Slime Vanner Tailings" under the heading of January 7, 1917, you state the assay per cent of copper to be 22.47. My calculators estimate, upon figures you have given us, the amount of copper should be 5.13. The discrepancy is so large that I will ask you to give it careful consideration, and, down that column I may say that every item of calculated assay is variant from your given assay, upon the figures given, although that is the most striking one.

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A. I am not certain that I have that one written up. I have no figures here that will enable me to give you that.

X-Q. 34. Well, with that suggestion of criticism on my part will you do as you did before, go over your figures very carefully?

A. I will have to send for the figures on that.

X-Q. 35. These are the computations that come from figures that you gave as to the recovery, including heads and tails and the discrepancy is so large that I think it ought to be explained.

A. All right.

X-Q. 36. Now, I asked you to furnish working drawings of the Janney machine. Are you able to do that now?

A. I made a request for them, but I didn't get them, yet.

MR. WILLIAMS: That is all for the present. I have got to go over these recalculations and will just postpone further cross examination.

MR. SCOTT: Our next witness will be Professor Taggart.

MR. WILLIAMS: I assume you do not care to put Dr. Sadtler back?

MR. SCOTT: I thought we would get all of the data that he is supposed to comment on, so as not to break his testimony again, as I was obliged to do before, in order to fill up the time.

Prof. Arthur Fay Taggart.

PROF. ARTHUR FAY TAGGART, a witness called on behalf of the defendant being first duly sworn testified as follows:

DIRECT EXAMINATION,

BY MR. SCOTT:

Q. 1. Professor Taggart will you state your full name, please?

A. Arthur Fay Taggart.

Q. 2. Will you state your education and experience in relation to mining and metallurgical matters?

A. I went to college, Stanford University, and hold a degree of Bachelor of Arts and the degree of Engineer of Mines from that university. Since graduation I have worked in various mills and done some examination work in foreign countries and for the last five years I have been instructor and assistant professor of mining engineering at Yale University and a consulting engineer associated with J. F. McClelland and L. W. Bahney at the same address.

Q. 3. Have you any connection at the present time with mining operations or mining interests?

A. None at all other than as consultant.

Q. 4. And how did you happen to become interested in flotation?

A. As a matter of academic interest rather than any other. It is more or less incumbent upon a university to keep abreast of the times, and when the discussion of flotation and the use of flotation became

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broad, it was immediately up to us to try to find out what we could about the subject.

Q. 5. Were there any formal actions or conferences in the university on the subject?

A. The question of flotation seems to involve considerably more physics than is included in <sup>the</sup> working knowledge of the average mining engineer and we thought in conference in the Mining Department that it would be well to get in touch with <sup>the</sup> Physics Department and try to get the Physics Department to supply the requisite knowledge of physical phenomena, while the mining department could supply the questions and point out the particular lines of research and that then a member of the physics department and myself could work together along this particular line.

Q. 6. Did you mention at the beginning of your testimony of your having had practical mining and metallurgical training?

A. I have had.

Q. 7. You stated the facts as to your practical experience, did you?

A. Yes, I did.

Q. 8. You did not state where, did you?

A. I have worked in the mill of the Nevada Consolidated Mining Company at McGill, Nevada, and in the mill of the Montgomery Shoshone Mining Company at Rhyolite, Nevada. I worked in both those mills as an operator of various kinds of metallurgical machinery, and I have assisted, with my associates, in the designing of three or four kinds of metallurgical

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plants, that work consuming a considerable portion of my time for the last three or four years.

Q. 9. Through how long a period has your investigation of the flotation process extended?

A. About two years.

Q. 10. Have you come to any conclusion as to what are the essentials in this so-called agitation-froth flotation process?

A. First, we must agitate and aerate a pulp with some reagents which will absorb at the gas-liquid and at the solid-liquid surface<sup>s</sup>; and after such agitation and aeration the pulp should be allowed to pass to some point, a box or cell, where the bubbles which have been beaten into or passed through the froth can rise to the surface of the mixture, carrying with them the load of solid matter, which ordinarily is the sulphide that it is desired to separate. The ordinary reagents used are oils or some fatty substance, acids or alkalis. The ores usually treated are those consisting of a sulphide or occasionally some other materials of adamantine or metallic luster, and a gangue consisting of some rock not having the adamantine or metallic luster, and ordinarily valueless.

Q. 11. Have you come to any conclusion as to what the function of the oil is in the agitation froth flotation process?

A. The oil seems to have two functions; first, to aid in the formation of a stable froth; second, to act as a selective agent for the separation of the sulphide from the worthless rock—and I hope that throughout

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the subsequent discussion the word sulphide will be taken to include such other few minerals as there are, which are not sulphides, and which yet are amenable to concentration by flotation. Graphite is one which is obviously not sulphide, and yet is so amenable.

Q. 12. Can you state in what way oil aids in the formation of a stable froth?

A. It acts in three ways I believe. It acts first, to reduce the surface tension of the water with which the ore is mixed. It also, by absorption or concentrating at the surface of the bubbles, within the pulp, forms a film, at the contact of which with the water in the pulp, there is formed an interface which is markedly more viscous than either the oil or the water or the mixture of the two. Finally, the oil will vary in concentration in the bubble film in such a way as to allow the bubble film to vary its <sup>strength</sup> resistance to external forces. In those three ways oil aids in the production of a stable froth.

Q. 13. Is there any simple experiment by which you could show, visually, that the oil does in fact reduce the surface tension?

A. There is. Would you like me to perform it now?

Q. 14. There will be time enough, won't there; it will only take a few minutes?

A. I think so, yes.

Q. 15. I will have the things gotten for you. Mr. Dosenbach knows where they are, does he?

A. Yes, Mr. Dosenbach knows.

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Q. 16. You might describe this experiment in advance?

A. I wonder if I might have the blackboard. I am rather accustomed to working with a blackboard.

Q. 17. There is one here; you may step to the blackboard.

A. (Drawing) This particular experiment that I am about to perform to show the reduction in surface tension by oil is to float a match on the surface of a body of water in a pan. The match will then appear in some such position as this (drawing). As soon as the water in the pan comes to rest, the match will be held stationary under the influence of the forces of surface tension, which are equal, and which act equally in all directions, and which I may represent by these arrows. Now, if on the surface of that pan we place a drop of oil at one side of the match—say, there—then the match will jump over against the side of the pan, away from the point at which the drop of oil is placed. The explanation of that particular phenomenon is, of course, the reduction of the surface tension of the water, due to the oil film upon it, and we find some such condition as this: If I represent this as the drop of oil, and the immediate sphere of action of the oil that spreads over the water by this curved line, then the force on this side, the surface tension, will be reduced in some such fashion as that, (drawing) while those on this side will momentarily remain as before, and of course the match will be pulled away by the preponderance of the surface force on the side away from the oil.

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Q. 18. Is there any simple or graphic way that you can state, just roughly, what this surface tension is?

A. It is a pull. You can consider the surface of the water itself as a stretched skin, similar to a sheet of elastic stretched over a ring or the head of a drum. Either of those things, while they are solid, are in the same state of tension, exactly, as the surface of any body of water. If we take the particular case of the elastic film and carry the parallel further, if you should place the match on the rubber film and cut the film at one side and thus reduce the tension on that side, of course the film would spring back toward the other side and carry the match with it. You would have there an exact parallel between the surface tension of water and the tension of that elastic film, pulling the match away in both cases from the place where it originally was, due to the preponderance of force on the side away from that where the tension was reduced.

MR. WILLIAMS: Will the professor furnish us drawings of the diagrams that he is making on the board?

Q. 19. I understand you are going to furnish little drawings the same as those you are putting on the blackboard?

A. I will, yes.

(The witness performed the experiment.)

WHEREUPON an adjournment was taken until Wednesday, April 25th, 1917, at 10:00 a. m.

Prof. Arthur Fay Taggart.

Wednesday, April 25, 1917.

MR. TAGGART ON THE STAND.

DIRECT EXAMINATION Resumed.

BY MR. SCOTT:

Q. 20. You have referred, Prof. Taggart, to the formation of a viscous film at the junction of the oil and water. Can you show this by an experiment?

A. I can.

Q. 21. I will ask you to do so.

A. May I first explain by blackboard drawings what I expect to have happen?

Q. 22. Certainly.

A. Now, for the purpose of showing that at the interfacial boundary between oil and water there forms a viscous film, I am going to take a beaker and place in it, at the bottom, some water, and for the purpose of making the phenomena to be observed more easily visible, I am going to color that water with red ink, and I will represent it here as so colored. After having placed the water colored with red ink in the bottom of the beaker, I will place above it a layer of oil, which, again, for the purpose of making the phenomena more easily observed, will be colorless. Then by means of a medicine dropper inserted with the point below the oil-water interface, I will release below the oil—water interface, some bubbles. The bubbles in rising will first strike the *cur* interface between the oil and wa-  
ter, and will drag that surface up in this fashion.

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(Figure 2) That particular phenomenon is indicative of the presence at the interface of a film which is considerably more viscous than the body of the water or the body of the oil; it will indicate more viscosity than the water, because it will have passed through the water freely until it strikes that film, and having been released from that film, as it will be later, it will pass through the oil freely, indicating, then, a greater viscosity at this interface than is present in either the colored water or oil.

(Drawing Figure 3). I will omit the medicine dropper, which, of course, will be present. Then after the bubbles have broken away through the viscous film of the interface, it will appear like this; then rising through the oil there will be the air at the center, surrounded by a film of considerable thickness of the colored water. That will pass up through the oil and arrive at the surface of the oil in some such condition as that, and when closely observed, some of these bubbles—all of them will not act in the same way—will show a red color at the surface of the oil, indicating that the film is still around the bubble. The film will have dragged down sufficiently when the bubble reaches the surface, so that the red color in some instances cannot be observed, and in those particular bubbles the condition will be this. (Figure 4)

Now, eventually both of those water coatings will drop from the bubbles and they will fall back through the oil in this cup-shaped form, and there will be apparent at the edges of the cup—the rim of the cup—

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some of the thin films that look almost like a red tissue paper. Now, it is the fact that the water, falling through the oil, preserves its shape rather than taking a spherical shape as would be ordinarily the case of a drop of water falling through a fluid such as air. That is an indication of the high viscosity of the film at the boundary between the water and the oil. According to the law that a mass will tend to a condition of least potential energy, and due to the further fact that a sphere is the solid whose surface is the least for its volume, and to the fact that with the least surface the particle of water will present the least potential energy, the particle should, if allowed to follow its tendency, assume a spherical shape. Now, the force of the surface tension that would tend to cause it to assume a spherical form, is overcome, in this instance, by the high viscosity of the film at the interface between the water and the oil, and you get, consequently, this shape, which is absolutely unnatural for a particle of water to assume, if it were not under conditions, as it is, where the viscosity of the surface is so great as to overcome the force of surface tension, tending to make it a sphere.

There will also be present in this mass of oil above the bubbles, if the bubbles are blown in with sufficient rapidity to agitate the surface of the interfacial film, particles of water shaped something like this, tadpole shape, as these are, again due to the excess of viscosity—the excess force of the viscosity of this interfacial film over the force of the surface tension of the water itself. (Figure 5)

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Now, I will perform the experiment.

Q. 23. Just state, professor, what you do as you go along and the stenographer will put it down?

A. First I poured the water into the beaker and inserted the bubble blower. Then I placed red ink in the beaker and then poured on to the surface of the ink a layer of oil, kerosene oil being used.

Q. 24. About how thick is the water layer and the oil layer?

A. The layer of water and the layer of oil are approximately an inch each in thickness. Now, first you will observe the way in which the interface pulls up as the air is inserted, indicating there the viscous film at the interface. As you will have observed, very quickly, the fact that some of the bubbles as they appear at the surface are coated with the red water. The holding of this red water layer at the surface is a momentary thing, merely. Then as the water falls back from the surface the cup shaped or bowl shaped drops of water may be observed. Finally, if I blow the air through rapidly, the little tadpole shaped particles will, I think, be noticed.

Q. 25. What are you trying to show now?

A. These bowl shaped drops of red water.

Q. 26. I don't know that the court gets a clear view of it. It is like a little shred of something falling. You will have to look very closely to see it.

THE COURT: Let me play with it.

THE WITNESS: If you release the bubbles near the center you get better results.

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THE COURT: You operate it, that is your trade, not mine. I see the distorted shape of the bubbles as they drop back.

THE WITNESS: That is the thing I wished you to see.

THE COURT: I have observed that.

THE WITNESS: The cup shaped bubbles, and the fact that there is a little fringe, as it were, hanging back around the cup where the film has been drawn out to a greater extent at the very edge of the bubbles.

THE COURT: As they come to the top they break in two, part of it go back?

A. Yes, the water goes back and the air stays up.

THE COURT: That which goes back is water entirely?

A. Oh, yes. It can be none other, because the water is colored and the oil is uncolored.

THE COURT: I mean there is no air inside of that that goes back?

A. No, no, there is no air.

MR. SCOTT: How would that be, doctor, if done in a jar about a foot deep? Would we have more time to look at it as it was dropping? Would that be any better?

A. I think it would be more visible.

THE COURT: I think I see what he is trying to illustrate.

MR. WILLIAMS: I would ask if your honor has seen the thing that is pictured there?

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THE COURT: No, I have not seen the distinct cup shape, it seems to me, going back. It appears to be in rather a globular form, some of these, going back.

THE WITNESS: Yes.

THE COURT: Are these solely water or is there air inside?

A. Those are solely water, unless you can see an occasional air drop. (Here the witness agitates the solution rapidly with the dropper.) Now, you see there are a great many of these small water globules at the top and no air there except occasionally an entrapped particle.

THE COURT: Your idea is as it comes up it is air and water there and the air stops at the top?

A. Yes, and the water falls back; and, due to the fact that the water is in contact with the oil, there is sufficient viscosity at the interface to overcome the surface tension. The experiment is, of course, to indicate the high viscosity of the film at the interface between the oil and the water.

THE COURT: I observe that lifting feature. I can't say that I observe as broadly as you make it there the saucer shape, but I can observe it goes back in a flattened form. Don't you think that these are all dropping back with a convex upper surface?

A. No, sir. The larger ones are but the smaller ones are not. There, did you see that one?

THE COURT: Yes, rather flattened out, as I say. I have observed that feature.

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A. And that one?

THE COURT: Yes, that is flattened.

THE WITNESS: Of course, they will assume a spherical surface as they go down.

THE COURT: I think I understand.

MR. SCOTT: You have drawn it in section on the blackboard?

A. Yes.

THE COURT: I understand what you mean.

THE WITNESS: The edges come up just as though they were tissue paper. As you get them larger the surface tension being a function of the area, is sufficient to overcome the viscosity. The smaller bubbles are more like the conditions in the flotation process where everything is beaten very fine. Then the force of viscosity is great enough to overcome the surface force.

Q. 27. MR. SCOTT: Can you show by some experiment, other than by actual flotation operation, the fact that oil tends to select a sulphide mineral in the presence of water and that water tends to select gangue in the presence of oil? Or, in other words, can you show that in the presence of water oil will selectively adhere to a sulphide particle in the presence of a gangue particle?

A. Yes. (Witness performing an experiment.) Now, I have placed in this cell a piece of galena and a piece of quartz and covered them so that the galena is about one-half inch and the quartz about an inch

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below the surface of the water. I am going to drop onto the surface of the water some drops of wood creosote, and ~~the~~ some of the drops will, due to their momentum and lessening of the surface tension of the water, fall through onto the respective minerals, and we will find that on the galena the oil tends to spread out over the surface, while on the quartz it tends to draw up into a globule and remain in that state. Now, if I may draw on the blackboard so it will be a little easier to see.

MR. SCOTT: I should like the record to show that we will have these sketches reproduced on paper for the record, these blackboard sketches.

MR. KREMER: That will be satisfactory to you, Mr. Williams? We will erase these and draw them on paper and submit them to you.

MR. WILLIAMS: Yes.

I think that the phenomena that we observed in the cell are presented in the sketch here (diagram 3.) The drops of oil on the surface of the galena tend to spread out and replace the water at that surface. The drops of oil on the surface of the quartz tend to draw up from it in the shape of a sphere. In other words, the water tends to push in under the oil at the quartz surface and replace the oil, so that we have ~~then~~ an instance of the selective action of the oil on galena or sulphide in the presence of water, and the selective action of the water on quartz or other gangue minerals in the presence of oil. It is, of course, this selec-

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tion which is depended upon in the flotation process for the separation of the valuable sulphide minerals from the worthless rock.

Q. 28. BY MR. WILLIAMS: Now, professor, I observe that the oil on the quartz is a globule which is quite perceptibly flattened out at its lower end, and, although it is not of very much importance, there is no doubt that what you have drawn there is slightly different from what that shows.

A. That is right; I will bring that down a little bit. (Drawing.) I believe that would be rather more in line with the phenomenon.

MR. SCOTT: I now offer diagram No. 3 just made by the witness in evidence.

Diagram No. 3 admitted in evidence without objection marked DEFENDANT'S EXHIBIT No. 126.

Q. 29. MR. SCOTT: You stated that the oil assists in the formation of a stable froth, and have shown by experiments the functions of the oil in such formation. What other conditions must prevail in order that the froth may be stable and persistent? <sup>matter</sup>

A. It must carry a load of finely divided solid <sup>matter</sup>.

Q. 30. What is the effect of the solid matter?

~~matter~~.

A. It is to increase the viscosity of the film very markedly.

Q. 31. Can you show that also by a simple experi-

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ment, the increase of viscosity due to the presence of solid matter?

A. Yes. (Drawing.) I will attempt four different experiments here to prove that it is the presence of solid matter which causes the formation of a stable and persistent froth. In the first place, if this represents the surface of a body of water, and I have floated on that body of water a little raft, like this,—this being a part of a match stick, and this being part of a match stick, and this a needle—(The reason that I am using this peculiar apparatus is that I want to be able to move the raft by means of a magnet, without touching the surface.) Then, if I float over here a chip, I will be able to turn that raft on the surface of the water without turning the chip, showing that there is no great viscosity in the interface between the water and the gas. That will be experiment No. 1 (Figure 1).

In experiment No. 2 I will use the same device, except that in this particular case I will dust upon the surface some finely divided ore (Figure 2) and then when this raft is moved by means of the magnet, it will be seen that the chip moves with the raft. In other words, that this surface is acting as though it were a solid. The viscosity has been so greatly increased by the addition of the solid matter to the interfacial film.

(Figure 3). Now, in experiment 3 I will take the raft and the chip and will place on the surface of the water a drop of oil sufficient to contaminate the

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water and lower the surface tension. At the interface between the oil and the water, there will be a viscous film which is characteristic of such an interface, and it will be seen that when I turn the raft, that the chip itself will not turn. By ordinary visual methods of measurement, as it were, there will not have been a sufficient increase of stability and viscosity of the surface by the mere addition of the oil to cause the increase in viscosity which is necessary to the formation of a stable and persistent film. Finally, (Figure 4), taking the same case, this oil-covered surface, I will dust some fine ore on it, and it will be seen that the chip again moves with the raft; that the surface has been stabilized and made highly viscous, viscous to the point of acting almost as a solid surface by the introduction of the finely divided solid matter into the film.

I will now perform the experiment. (A pan of water, the raft and a chip.) You will see that I can move this raft and there is no corresponding motion of the chip. (Adding dust.)

Q. 32. MR. WILLIAMS: What material have you dusted in there?

A. I think that is some Butte & Superior ore.

Q. 33. BY THE COURT: Where is that chip?

A. The chip is over here. There must have been some grease on it from carrying it in my pocket, which causes the film to pull away from it. Now, you will notice that I can move the entire surface.

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Q. 34. MR. SCOTT: How would it do to add a new chip?

A. I hardly think it would make any difference.

Q. 35. BY MR. WILLIAMS: Cut two or three chips off so as to get down to a clean surface.

(Witness cutting several chips off pencil.)

Q. 36. BY THE COURT: Does your magnet act on the ore as well as on the needle?

A. Not on this ore; at least that is the presumption. I think that I can show here that it does not. (Sticking magnet in a bunch of ore.) I think it can be seen very obviously that the whole surface there moves.  
• (Holding magnet near raft).

Q. 37. BY THE COURT: If you took your pencil would it move that scum?

A. I will try that. Yes, it does.

Q. 38. What does this illustrate now?

A. The increase in the viscosity of this interface between the gas and the liquid by introducing into that interface the finely divided solid particles.

Q. 39. Then it does not matter how you move the raft?

A. Not at all, not at all. Now, I will take another small pan, and I will put in water and the raft and a chip and I will add some wood creosote oil. There is no doubt of the contamination of the surface there.

Q. 40. BY THE COURT: What is this?

A. Here I am going to show that the increased viscosity of that interface is due to the introduction

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of solid matter, rather than to the introduction of the oil.

Now, you will see that the raft can be moved without the sphere of influence of the movement of the raft extending to the chip, although it can be seen by observing the film between the two arms of the raft, as it were, that that surface itself is acting like a solid; that is, the increase of the viscosity of the surface by the oil is sufficient to cause it to act almost as a solid through small distances, but that it is not sufficient to make it act as a solid over a considerable distance, and does not indicate the high viscosity that will be indicated when I put the ore on. (Sifting on ore dust.)

The surface has become so tough now that I have to get very close with the magnet to influence the needle.

Q. 41. BY THE COURT: Your mineral breaks up.

MR. SCOTT: It needs more mineral, I guess.

(Witness added more dust.) I think the motion is shown here ahead of the raft, practically under my finger.

MR. SCOTT: I offer the diagram just made by the witness and marked "No. 4, A. F. T."

Diagram admitted in evidence and marked DEFENDANT'S EXHIBIT 127.

Q. 42. Now, Professor Taggart, will you explain the relation of the experiment you have just performed to the permanency of the film, in flotation operation?

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A. I stated yesterday that the functions of oil in the flotation process were two: First, to assist in the formation of a stable froth; second, to assist in the selection of the sulphide mineral from the gangue. I said that the ways in which the oil assisted in the formation of a stable froth were: first, to decrease the surface tension of the water in the pulp, and I showed the decrease in the surface tension of water by means of oil, with the experiment No. 1. Then I stated that at the interface between oil and water there was formed a film whose viscosity was markedly greater than that of either the water or the oil or of the mixture of the two; and I showed that this morning by means of the experiment No. 2, the colored water bubble experiment. I said there that the oil assisted in the formation of a stable film by concentrating in the film and, being present in the film as a contaminant, having the power to move in the film and thus change the oil concentration in the film at any point in a direction which would tend to increase the resistance of the film to external forces. That I have not been able to illustrate by experiments. It is a matter, rather, of reasoning. Then, the other function of the oil, the selective action for sulphide as compared to gangue, is illustrated in experiment No. 3, in which it was shown that the oil tended to displace water at the surface of the sulphide particle, and that water tended to displace oil at the surface of the gangue particle. It is true, however, that in addition to the stabilizing influence of the oil alone, it is necessary for the for-

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mation of a persistent froth that there be present in the bubble film a load of solid matter, and the effect of that load of solid matter in stabilizing and making persistent the bubble film is shown in experiment No. 4 just performed.

Q. 43. If we were to shake a bottle containing water and a little oil and then afterwards to shake a bottle similarly containing water and oil, but in addition powdered ore, is it your opinion that the result of the two operations would confirm the conclusion drawn from your experiment with the little raft this morning?

A. Yes, sir.

Q. 44. In the first instance, what would happen?

A. In the first instance, you would get some bubbles that would persist for perhaps a fraction of a second or a second, but obviously longer than they would persist if pure water alone had been placed in the bottle. In the second instance, you would get some bubbles that would persist considerably longer than the bubbles with oil and water alone. Just how much longer I would not dare say because that is a question of the quantity of sulphide present and the degree of agitation.

Q. 45. The second operation, with the oil, water and ore, is illustrated, is it not, by the two tubes containing the molybdenite froth which stand before the court?

A. That is what you should get with consider-

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able agitation. I did not see those experiments performed so that I do not know.

Q. 46. Can you state generally the condition necessary for the commercial success of a flotation process, as to the material treated, and so forth?

A. There are two conditions. First, that the solid material which passes into the froth shall be preponderantly sulphide, assuming that you are attempting to concentrate a sulphide from a worthless rock; and, second, that a very large percentage of the total sulphide present in the feed to the apparatus shall pass into the froth.

Q. 47. What is the effect of the emulsification of the oil and the agitation, as practiced in the flotation process?

A. As the process is ordinarily practiced the pulp containing the proper reagent, is placed into a device for agitating it violently. The idea of such agitation is to break up the oil that has been introduced into an extremely large number of extremely small particles or globules and at the same time to cause a certain number of the sulphide particles present in the feed to meet or come in contact with those oil globules and become coated with oil. Of course, at the same time that the sulphide particles are coming into contact with the oil globules, particles of gangue are also coming into contact with them, but, due to the tendency of the oil to replace water at the surface of sulphide, the sulphide particles will become

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coated with the oil; and, due to the reverse tendency of the water to displace oil at the surface of gangue particles, the gangue particles will become coated with water. Then after the agitation in this primary agitator, in the so-called "emulsifying cells," the pulp is passed to another agitator which is so arranged that there is a circuit through into a box, a settling or separating box, in which there is no agitation and from which the pulp can pass back again either into the cell which it just left or through suitable passages into another cell. In these so-called "beater cells" of the process the pulp is filled with an enormous quantity of small air bubbles. Then, during the process of agitation, these bubbles, in a purely mechanical manner, and under the ordinary laws of probability, will come into contact with either small globules or oil-coated sulphide particles, or both, or neither. Those bubbles which come into contact with an oil globule or an oil coated sulphide particle will immediately become coated at the air-liquid contact surface with a thin layer of oil. We have then the condition for concentration, for the separating of the sulphide particles from the gangue particles. That is, we have an air bubble surrounded by an oil film, and outside of that oil film the watery mass of the pulp. We have then, at the surface of the air bubble, a low surface tension due to the contaminant which is absorbed or concentrated at the interface between the gas in the bubble and the surrounding liquid. There is

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present the viscous film which is characteristic of the interface between oil and water. We have also a place at which the sorting of the sulphide from the gangue can be done, and as sulphide particles and gangue particles are present in this interface for sorting, the sulphide particles, owing to the tendency of oil to replace water at the surface of the sulphides, will pass into the oil layer at the surface of the bubble; while the gangue particles, due to the tendency of water to displace oil at the surface of gangue particles, will be rejected at that interface and passed back into the mass of the water. Now, in a mass where there are present such stupendous numbers of bubbles and oil globules and oiled sulphide particles and unoiled sulphide particles it is obvious that there will be a stupendous number of chances offered for the sulphide particles to stick to and stay at the surface of the bubbles. When the bubbles arrive at the surface of the liquid, as they will when the pulp passes out into the separating chamber and there is a quiet place offered for the difference in specific gravity to allow the solid coated bubbles to so rise, there is a sufficient coat of sulphide particles to stabilize the bubbles and cause them to be persistent for a sufficient length of time to allow them to be scraped off or taken off by some means from the surface of the box and thus be separated completely from the gangue, which sinks in the box and is carried out at another point. The froth that rises will, of course, be pre-

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dominately sulphide and the solid that sinks and passes out in the so-called tailings discharge of the machine will be predominately gangue.

Q. 48. What is your opinion, Mr. Taggart, as to the effect of acid in the agitation-froth flotation process?

A. I think the acid has perhaps two functions. In the first place, acid tends to absorb at the surface of gangue particles, that is to concentrate at the surface of gangue particles, in a manner exactly similar to that in which oil tends to absorb or concentrate at the surface of water. Now, the result of this tendency of acid or acidulated water to absorb at the surface of gangue particles is to insure that the gangue particles will be wet with—that is will pass into and will remain in—the water part of the pulp. The acid also aids in flocculating or agglomerating into rather large masses the very fine particles of gangue and thus aids in keeping these gangue particles out of the concentrate froth.

Q. 49. Have you formed any conclusion as to the effect of heat in the flotation process?

A. Heat, I think again has two functions. In the first place, it decreases the viscosity of the oils and hence aids in the distribution of the oil at the surface of the air bubbles. Even more prominently, however, it acts as a means of flocculating the finely divided gangue; and this flocculation is almost essential.

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Q. 50. What is the word you use?

A. Flocculating, that is the drawing together into masses of a lot of small particles. This flocculation is almost essential to the production of a clean froth; that is, one that is not carrying a considerable proportion of gangue.

Q. 51. MR. WILLIAMS: Clean concentrate, did you say?

A. Clean concentrate, yes.

Q. 52. MR. SCOTT: You have stated that this flocculation of the finely divided gangue caused a reduction of the percentage of gangue in the concentrate, but have you any explanation for that statement?

A. In the agitation in the so-called emulsifier cells and in the subsequent agitation in the ~~b~~eater cells of the flotation machine it is unquestionably true that an even larger amount or proportion of gangue particles is presented to the bubble surface than of sulphide particles, provided that the amount of gangue present in the feed is greater than that of the sulphide. The force tending to reject the gangue is a function of the surface of the particles, of the area of the surface. The greater the area, the greater this force. The film at the bubble surface or surrounding the air in the pulp is viscous, as we have shown, and in the case of these various small particles of gangue the viscosity of that film may be sufficient to hold the gangue particles in there against the force—the surface force, tending to throw them out. Now when the fine par-

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ticles are agglomerated together or flocculated, they present a very considerably increased surface, and there is consequently an increase in this surface force, and the increase in the surface force is greater than the increase in the periphery of the agglomerate with respect to the original particles. The force of the viscosity at the interfacial film is a function of the circumference, as it were, of this flock. The periphery of course, as you increase the flock, increases as the radius, or as the diameter, in other words as the first power of that particular dimension of the body, while the area of the surface increases as the square of the radius. Consequently as you increase the size, you increase the area as the square of the radius and increase the surface force as the square of the radius, while you increase the circumference only as the first power of the radius and, hence, increase the viscosity only by the first power of that particular function; so that the increase in the surface force then is greater than the increase in the viscosity, with the increase in size of the particles; and consequently the surface force will tend to throw the larger flocks out while it is not sufficient to throw the smaller particles out against the viscosity of the film at the bubble surface.

I might say here that the increase in surface force is even greater than the increase of the square of the radius, due to the irregular shape of the surface of the flock. If the small particles which are flocked together are spherical, then the reasoning as to the

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first power and the second power of the radius would hold directly; but where the particle has a very much greater surface due to its corrugations than the sphere, then the increase in the surface power is even greater than would be true in the case of the sphere.

Q. 53. Is there anything in <sup>the</sup> theoretical basis of the agitation-froth flotation process that indicates a critical point in the quantity of oil relative to the ore?

A. Absolutely none that I can see.

Q. 54. What are the conditions that determine the amount of oil that must be used?

A. I think that the amount of oil that must be used depends upon three things: The amount of sulphide matter that is present in the feed, the amount of water that is present in the feed, that is, the degree of dilution, and the degree of aeration in the feed.

Q. 55. Will you state the relation between the amount of aeration or agitation and the amount of oil necessary?

A. If we consider in a cell or in a particular operation all things constant, except the degree of aeration, then any particular bubble in the machine will have a path whose average length is the same. There will, of course, be some bubbles that will go through the machine very quickly; there will be some bubbles that take a long time, that pass around and around in the beater cells before going out into the Spitzkasten; but taking the average of all the bubbles in the machine, then most of the bubbles will not depart very greatly from this average. The number of bubbles and the size of

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the bubbles with a given degree of agitation will also be approximately a constant. The number of globules of oil and the size of the globules of oil and the number of particles of sulphide—coated and uncoated with oil—will all be approximately constant figures, other conditions being the same, with a given degree of agitation. This means, then, that each oil bubble will carry approximately the same amount of oil, will have met approximately the same number of globules of oil and the same number of oiled particles; consequently there will be a certain quantity of oil required to coat a given quantity of bubbles. If, now, by increasing the agitation, you beat in twice as many particles of air, the other things remaining constant (the number of particles of various things)—the number of bubbles will increase; we may assume for the sake of argument that they double, which they may not, of course, and if you have had present in the first instance just enough oil to coat the number of air bubbles that were present with the first degree of agitation, you will obviously not have enough oil present to coat the greater number of bubbles that will be formed with **an increased amount of agitation**: therefore, as you increase the degree of agitation it will be necessary to increase the amount of oil that is to be used, if it is expected that the bubbles are going to arrive at the surface coated with a sufficient quantity of oil to perform their function in the process.

Q. 56. Now will you state similarly what the relation is between the amount of sulphide present in the ore and the amount of oil necessary?

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A. The reasoning, of course, is entirely similar. In order to coat a given number of sulphide particles with oil—and you must assume that the great majority of the sulphide particles that are saved must be coated with oil—it is necessary to have a film of some certain minimum thickness on each particle. Now, as you increase the number of particles, it means, of course, that you must increase the quantity of the oil fed into the machine in order that each sulphide particle may have its coating of the minimum thickness of oil.

Q. 57. How does the amount of water present in the pulp affect the quantity of oil necessary?

A. Other things being constant, if you double the amount of water in a pulp there will be present in each cubic foot of pulp one-half the number of sulphide particles that there were present before. It is necessary, however, in order to insure that all the sulphide particles or a very great majority of the sulphide particles in the feed shall meet a globule of oil or an oil-coated air bubble, that there shall be present in each cubic foot of the pulp a certain minimum number of oil-coated air bubbles. In order to coat these air bubbles, a certain quantity of oil must be used; but where the pulp is dilute, you have to supply this number of oil-coated air bubbles for a very much smaller number of sulphide particles than when the pulp is thicker. Consequently the amount of oil necessary will depend upon the degree of dilution; as the dilution increases, the amount of oil necessary will increase.

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Q. 58. Suppose a soluble frothing agent were used, would the dilution of the pulp have a similar effect?

A. Yes, sir.

Q. 59. I think that it is a fair statement of what you have explained that in your opinion the amount of oil necessary is dependent on the amount of sulphide in the feed and the dilution of the pulp, rather than on the amount of solid matter?

A. Yes.

Q. 60. Is it your opinion that the attachment of air directly to the sulphide particles has anything to do with the agitation froth flotation process?

A. No, it has not.

Q. 61. Have you any experimental data in support of that conclusion?

A. I have examined a large number of bubble films under the microscope, the particular method followed being to take some newly formed froth on a ring, in such a fashion that I could quickly examine, first one side and then the other side, thus insuring that I was seeing what had been the outside of the bubble and also the inside of the bubble. In such examination I have found that in freshly formed films a very large majority—and by that I mean in the proportion of ten or twenty or thirty or forty thousand to one—of the particles present in the film, are entirely within the bubble film; that with just a very few exceptions the solid particles are at no point in contact with the air. Now, there need be a little care exercised in this particular examination, be-

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cause in a film that has stood for a few minutes, if the film is sufficiently loaded with solids to remain for a considerable length of time, the larger particles of solid matter present in the film will commence to poke through; they do not break up the film, but the particles poke through, and the film will draw down over them, leaving the solid particles very apparently sticking through, and such is not the condition as the fresh froth reaches the surface. If, however, you attempt to photograph, it is necessary, of course, to get a froth or a film that will stand for a considerable length of time—that is, a thick film, and I have not yet been able to photograph within the thirty seconds or a minute that are necessary, if I would insure that all the particles remain within the film—so that photographs all show some particles sticking through. However, it is possible, I think, that you can examine it here through the microscope—examine some freshly formed films and see that the particles are almost all within the bubble film. I will perform that experiment if you like.

Q. 62. Well, I think you might as well do that.

A. I think we have the square jar machine here.

Q. 63. BY THE COURT: You say the particles are in the film of oil surrounding the air?

A. There will be a bubble film with air inside, and a surface with air outside. Now, the solid particles are completely within that film, and the film will raise up over the solid particles and, underneath, the film will come down under the solid particle, so that the particle

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is completely enclosed within the film, and there can be no question of the attachment of air for the particle itself. It is true that there is some selective attachment of air for sulphide particles as opposed to gangue particles, and in some of the earlier investigations of the subject it was thought that this actual attachment of the air for sulphide in preference to gangue was an explanation of the flotation process; but by examining these froths, it can be seen that air is not in contact with the solid particles at all as they come to the surface in the bubble film.

Q. 64. Could you illustrate that with a little diagram, the position of the mineral particles in relation to the bubbles?

A. I can. If this particle is here as the small particle in the film, then one surface of the film will come along in this fashion and rise up over and surround the solid particle, while the other portion will come over in this fashion and then come down around the solid particle in that way (drawing). Now, after that film has stood for a short length of time, the condition presented will be something like this (drawing). The solid particle will stick out in such fashion as that. This film has already been raised to the surface; flotation has been done; all that remains is to scrape it off within a period of twenty or thirty seconds or a minute or so subsequent to this. This is the kind <sup>of</sup> activity in the ordinary separation in the machine.

Q. 65. In referring to the face that was active in

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the process, did you have reference to the upper or the lower drawing in the sketch?

A. To the upper drawing, the one that is numbered No. 1; and the second represents the condition after the bubble film has been some time at the surface.

Q. 66. Now, will you mark that diagram 5?

A. Diagram No. 5.

MR. SCOTT: I offer this diagram in evidence, No. 5.

Admitted without objection marked DEFENDANT'S EXHIBIT No. 128.

Q. 67. Does it require a fresh froth in order to see this?

A. Yes. I thought he had the square jar machine down here, but it seems he has not.

Q. 68. THE COURT: I do not understand what film that is; is that the oil coating of the air bubble?

A. Yes, that is the film around the bubble. The situation of the surface, if you consider this just a single bubble, will be something like this. Now, if I enlarge that particular film—

THE COURT: I think I understand now, Professor; I did not know for sure what you meant.

Q. 69. BY MR. WILLIAMS: Which is the outside of the bubble in your diagram; is it the top?

A. It does not make the least bit of difference.

Q. 70. BY MR. SCOTT: Referring to the circulating load in the flotation process, that is, the return of the middlings to the head of the machine, what is

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your opinion as to the condition of the oil that comes back with the middlings, that is, whether it is all adhering to and appropriated by mineral particles or not.

A. It is not, I think, all adhering to and appropriated by mineral particles.

Q. 71. What is your reason for so stating?

A. We are speaking now of the agitation froth process?

Q. 72. Yes.

A. In the later cells of the agitation froth machine, the froths are much more fragile, much less persistent than the froths in the earlier cells. Now, the persistence of the froth depends, of course, upon the load of solid matter<sup>contained</sup> in it. The less persistent froths, therefore, will have a smaller load of solids contained within them than the more persistent. It is the less persistent froths that are circulated. The bubble film itself consists of a complete layer on each surface, in which is concentrated oil, and the concentration lessens as you pass toward the center of the film. In other words, the whole area of the bubble film has oil upon it. If the solid particles do not occupy the whole area of the bubble film, then it must be true that between the solid particles there are areas of bubble film unoccupied by solids. But as the oil covers the whole area of the bubble film, then these areas which are unoccupied by solids are yet occupied by oil, and that oil is, of course, not appropriated by the solid matter, and is therefore unappropriated oil which is available for use in the circulating load as it comes back into the machine, for coating sulphide particles in the new feed.

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Q. 73. How do you explain the fact which has been referred to that in flotation plants where heavy collecting oil is used in large bulk in connection with a lighter, so-called frothing oil, and the heavy collecting oil is discontinued, the froth has been observed to cease entirely?

A. The heavy collecting oil, so-called, is used in much greater quantities than the light, frothing oil; in other words, the amount of the light frothing oil added per ton of sulphide mineral present in the feed is extremely small; so small, in fact, that it would not coat enough air bubbles and collect enough solid matter to satisfy the requirements for the formation of a stable froth.

Q. 74. Instances have been referred to by witnesses in which the use of a large amount of oil made a more abundant froth than smaller quantities. Have you any explanation of that?

A. It is unquestionably the case in the agitation or in the beater cells, that a considerable number of air bubbles, under ordinary circumstances—particularly where small quantities of oil are used—pass through the process of agitation and on through the Spitzkasten without becoming coated with oil, and with solid particles. As the amount of the oil is increased, the number of chances and the probability of all the air bubbles becoming coated with oil, of course, increases, and the number of bubbles which do become coated with oil will increase according to these chances and probabilities. It is also true that in the ordinary agi-

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tation-froth process the bubbles—particularly in the first cells—are coated more heavily with solid particles than is absolutely essential to their persistence for the length of time required for their removal from the machine; so that there is present then sufficient sulphide to distribute over these additional oil bubbles that are formed when more oil is put in, and stabilized them, and thus increase the number of stable bubbles in the froth. In other words, increase its volume. I think that is the explanation of the increase in the volume of the froth with increasing oil.

Q. 75. It has been stated that the use of the oil referred to as Jones oil produces a very voluminous froth when used for the flotation of vanner tailings, but that this phenomenon is not observed when the same oil is used upon the low grade vanner concentrate. Can you explain that fact.

A. I have just stated that there was present in the froth of the first cell of the ordinary agitation-froth machine an excess of sulphide material above that required to stabilize the froth for the required length of time. The lessening of the amount of solid material in the froth means a lessening in viscosity of the bubble film while it may yet remain sufficiently viscous to be stable for the necessary length of time. However, as one of these lightly loaded bubbles comes to the surface the air contained within it of course tends to expand with the lessening of the pressure due to the decrease of hydrostatic head and the film will therefore expand as far as the viscosity will allow it. Vanner tailings

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are low grade, that is they contain a small per cent only of sulphide mineral. Consequently there will be a relatively small percentage of the stabilizing sulphide material present in the froth and the tendency of the bubble to expand as it reaches the surface is not overcome by the viscosity of the froth. The bubble will therefore expand and make the very voluminous froth that is complained of in this particular connection. On the other hand, in the vanner concentrate machine the feed is richer, contains a larger amount of sulphide. There is, therefore, a considerably larger load of sulphide present in each bubble. The degree of agitation being about the same, the viscosity of the film surrounding the bubble is so great, due to the greater amount of sulphide present in the film, as not to allow the bubble to expand under the decrease in pressure. Consequently you get the characteristic small-bubble heavy froth with these vanner concentrates and get away from the over frothing that is complained of with the Jones oil and vanner tailings.

Q. 76. Will you state whether or not it is essential, in your opinion, that the sulphide particles be coated with oil before leaving the emulsifier or before entering the flotation machine, in order that they may be emulsified in the bubble film?

A. It is not essential. In the beater cell we have present oil globules or air bubbles in numbers that are almost beyond comprehension, and while it is possible that a sulphide particle not yet oiled may not become oiled in the beater cell, yet it is extremely unlikely that

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any sulphide particle can miss meeting one of the oil bubbles or the oil globules in the beater cell when there are such enormous numbers present. It is a pure question of chance.

WHEREUPON an adjournment was taken until 2:00 P. M. Wednesday, April 25th, 1917.

2:00 o'clock P. M. April 25, 1917.

Q. 77. If you are ready now, professor, we will go ahead with the experiment of examining the bubbles under the microscope taken from the flotation froth.

A. All right, sir.

Q. 78. Describe first how the froth is to be made, and what of.

A. This experiment is intended to confirm the drawing which I made on the board, diagram 5, showing that the solid particles within the froth are, most of them,—almost all of them, included within the bubble film; by that I mean, not inside the bubble itself and in contact with the air inside, or outside the bubble and in contact with the air outside, but in contradistinction to that, entirely included within the film of the bubble itself, and not in contact with the air either on the inside of the bubble or on the outside of the bubble.

I hope to show that, by taking the froth on a ring and placing the ring under the microscope and examining first one side of the film, which will be stretched on the ring and which will be the outside of the bubble

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as it appeared in the froth; then turning the ring over and examining the other side, which will represent the surface of the bubble which was toward the inside. The froth which is to be used will be made by mixing a charge as follows, in the Janney experimental machine: 400 grams of Butte & Superior ore; 2,000 c.c. of water at a temperature of 30° C.; 9/10 of a cubic centimeter of sulphuric acid of a specific gravity of 1.84; 1 c.c. of copper sulphate solution; 5.2 c.c. of oil mixture—of the particular mixture which is used in the Butte & Superior mill. That will be agitated, and in order that I may get a froth which is not so heavy as to be classed almost as a mud, I will skim off the first froth that comes up and get down to some of the later froths, where the particles are more widely separated in the film, and therefore more easily to be observed.

Q. 79. Professor, you might state to the court in a very few words how that Janney machine works. It has nothing to do with this experiment, but it is a convenient time to explain it.

A. The machine consists of a cylindrical portion, in which is a central shaft carrying two beaters, one about this point in the lower part and one at about this point in the upper part of the machine. At one side is the separating box in which the solution or pulp is much quieter, naturally, than it would be in the agitator. The separating box is connected with the cylinder at the bottom and at the upper portion. Surrounding this cylinder is this annular box, into which the froth is thrown by means of the beaters. The froth is

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then discharged onto the surface of the water in the separating box. The froth, of course, stays at the surface, so that the liquid containing the gangue, as the stuff is thrown out, settles and is drawn back in again through the opening at the bottom, thus having a circulation which, in some ways, is similar to the operation of the Janney machines which are used.

THE COURT: The court is assuming he is doing the thing he said he would, and these other gentlemen are watching. I don't know as it will add any to see him put in the material.

MR. WILLIAMS: I think it would be well to keep an open space between the eye of the court and the machine.

THE COURT: When it is operating.

THE WITNESS: (Gathering bubbles from the froth produced by the Janney machine.) Now, this has to be looked at rather rapidly. I think that will thin down. You see there is a bubble both this side and this side. Now, I have broken that so that I have both the inside and the outside of that bubble face as it stood. Now, if we can look at it under the microscope I think your honor will see that the film comes up and surrounds the large particles.

Q. 80. THE COURT: How many diameters is that?

A. Somewhere between 25 and 40. I haven't it exactly.

Q. 81. THE COURT: These protuberances that are bright, by reason of the reflection, those are what you term the mineral inside the film?

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A. Yes, the film comes up over that. You will notice the film is raised up, a little mount above that. And I will show you the other side (turning the material over).

Q. 82. MR. WILLIAMS: Which side is that that is exposed?

A. I don't know. There is no difference between the sides.

Q. 83. MR. SCOTT: Will those particles project through the film if we leave it there five minutes or so?

A. They will if the film does not break before. If the film is sufficiently viscous to last. What I got there was a bubble somewhat like that with the wire coming right along the side of this and then I took my pencil and pricked one side of that so that I had the inside and the outside of the bubble.

Q. 84. MR. WILLIAMS: What you really have is a film of water containing mineral?

A. A film of water and oil, a film containing oil concentrated at the air surfaces.

Q. 85. Both surfaces?

A. Both surfaces, and in that film the solid material.

Q. 86. Where is the water?

A. The water is at the center of the film and the water is most highly concentrated at the center of the film, the oil most highly concentrated at the surface.

Q. 87. Now, I am looking at this through the microscope, and what I see is a few particles here and there that are metallic, and a great deal of material that is apparently gangue. Is that right?

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A. It might be. I would like to look and see whether I would check your observation. If you will qualify by saying apparently gangue, I will agree with you. I would not attempt to make the distinction between the rather light particles that are present and the gangue without more practice with the microscope on that particular ore.

Q. 88. Now, I can not see anything covering the metallic particles, can you?

A. I think if you will look now, Mr. Williams, that you will find that the surface of the film comes up over the larger particles in an entirely smooth and regular way, different from the irregular surface that would be presented if you saw the mineral itself.

Q. 89. I see nothing except bright metallic surfaces protruding upward.

A. Through the film?

Q. 90. I am unable to recognize the film. Can you tell me how to recognize it?

A. By its rather moist and somewhat liquid appearance, as opposed to the decidedly not-moist and decidedly not-liquid appearance of the solid matter.

Q. 91. Isn't it a fact that the metal particles are cleaned by this operation of terrific agitation to which they are subjected?

A. What do you mean by "cleaned"?

Q. 92. I mean polished, or the gangue removed from them?

A. No, sir.

Q. 93. You would expect to find dusty surfaces in that pulp?

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A. Not dusty, no.

Q. 94. Wouldn't you expect to find clean surfaces of metal in that pulp?

A. Of the metallic particles, yes, but not particles that had been cleaned due to agitation, but rather due to the preliminary grinding that they had received.

Q. 95. And being cleaned, wouldn't they be bright?

A. They would, but they would not be liquid looking. They would not have the smooth and regularly curved surfaces, but would have angular surfaces. I think perhaps in order to show you the difference, I should take some of the original ore and put it in there and let you see the difference between the angular appearance of the dry ore and the smooth appearance of the liquid film.

Q. 96. In any event those metallic particles are to some extent coated with oil, are they not, as they exist in that bubble?

A. Unquestionably, sir.

Q. 97. And they would still be coated with oil if they were separate and apart from the bubble?

A. Unquestionably.

Q. 98. And that would make them glisten, wouldn't it?

A. Yes. They would not, however, I wish to state here, be in contact with the air if they were entirely coated with oil.

MR. WILLIAMS: That is all the cross-examination as to this particular experiment.

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DIRECT EXAMINATION (Resumed).

BY MR. SCOTT:

Q. 99. Professor Taggart, will you arrange in the microscope some of the dry ore that was used in this experiment, and if it is practical also expose some of the mineral particles out of the froth, covered by oil but separate from the bubble films, if that would be practical.

A. Yes.

Q. 100. Well, since you are not quite ready we will ask another question. Can you explain how it is possible that the amount of oil per ton of solids in a flotation system having a circulating load can be greater than the amount of oil initially fed into the machine per initial ton of feed?

A. I think I can explain that statement. It is not exactly accurate. There is present in the circulating load, naturally, no more oil than was originally fed in with the pulp; there is no device of course in the machine for the manufacture of oil. There is, however, this condition present, that the oil passes through the machine—the oil in the circulating load—at a rate considerably greater than the rate at which the original oil is fed in; or at least that is a possibility; it may be the other way. I think I can illustrate by a diagram just the distinction that I am trying to make between the amount of oil and the rate. If you consider this drawing to be the cylinder of a pump, this to be the piston and this the piston rod; S, the suction end of

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the pump and D the discharge end of the pump, and that this is a pipe running around from the discharge end to the suction end; and if we assume that there is an opening in the top of that pipe, so as you could fill this whole system with oil, the pipe at this end of the cylinder (D).

Q. 101. You might indicate by letters as you go along.

A. The point for the introduction of the oil I will mark A; and if we introduce at A enough oil to completely fill the system, the pipe, the discharge end of the cylinder and as much of the suction end of the cylinder as is not taken up by the piston rod itself, and if we assume further that the total quantity of oil in there is, we will say, 25 gallons, now we start pumping, and the oil, of course, will circulate—in this fashion, around through the system. Now, if at any time we were to open this pipe and for a given length of time collect the oil that discharged—we will say for 30 seconds, and in that time we collected a gallon of oil—which is all within the realms of possibility—then we would have oil passing through that system at the rate of one gallon in thirty seconds, or 2,880 gallons per 24 hours, while you have only present in the complete system, 25 gallons of oil. It is a question of rate.

The same thing applies in the return system in the flotation process; there is present all the time an oil circulating, similarly to the oil circulating in this system. It is measured by cutting the stream of pulp for a given amount of time, by analyzing the pulp that is cut

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for oil, and by drying some of the pulp and weighing the solids in it. We have then the rate at which the oil is flowing through that system, and the amount of the solid that is flowing with the oil in the circulating system, so that there is cut from the middling charge in a second a given number of pounds of solids, accompanied by a given number of pounds of oil, which is the oil in the circulating system. If this is greater than the amount which is meant to be fed to the machine per ton of solid matter entering the machine, then it should be credited to the new oil which is necessary in order to bring the total amount of the oil entering the machine up to the desired proportion to the total amount of solids entering the machine. If the amount of oil is smaller than that fed in with the new feed, then new oil has got to be added in excess of that required by the new one. In order to furnish to the old pulp circulating through the machine enough oil to bring the oil in that pulp up to the amount that is put in with the new feed, and the total oil entering up to the proper proportion to the total amount of solids passing through the machine.

MR. SCOTT: I offer in evidence this diagram just referred to by the witness and being marked "Diagram 6 A. F. T."

Diagram admitted in evidence and marked DEFENDANT'S EXHIBIT No. 129.

THE WITNESS: (Producing a sample grain of ore and placing same under the microscope.) I think

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that will show, Mr. Scott, the desired angular character of the particle and I think Mr. Williams may be able to see a difference between the rather angular particle there and the rounded surface of the film as it comes up under the original particle.

Q. 102. What have you placed under the microscope?

A. I have placed that portion of the ore which remains on a screen of approximately 80 meshes I think, yes, 80 meshes.

Q. 103. What is the nature of this ore you put on here now?

A. It consists of a large particle of solid material from this Butte & Superior ore which was used in the previous test.

Q. 104. This is some of the same ore that was in the froth?

A. No, but some of the same ore that was fed to the machine. I will take some of the ore in the froth later. You can notice the angular character of it. This is some of the material out of the froth. Note how much more angular that is.

Q. 105. MR. WILLIAMS: That is some of the concentrate you have just put into the microscope?

A. Yes, sir, that has been vanned out of the froth.

Q. 106. Why does it contain so much more of the gangue particles, large gangue particles than the one which you first showed?

A. I am sure I cannot say, sir. It was taken from a different part of the froth and furthermore the oil

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and the very fine particles which conceal what is in the froth have been removed here, making the presence of any large gangue particles much more easily discerned.

Q. 107. It is your understanding then that the free oil has been removed from this concentrate?

A. No, some oil unquestionably has. It would be very easy to prove that there was still oil present there.

Q. 108. But some oil has been removed from it?

A. Oh, unquestionably, yes.

Q. 109. MR. SCOTT: You referred this morning to the relation existing between the oil and the amount of sulphide mineral in the ore, between the amount of oil and the number of air bubbles or degree of aeration, and the third relation between the amount of oil and the dilution or the amount of water in the pulp. I wish you would state whether either of these three relations . . .

P. 2991, L. 20, insert "ore or in comparing any two given ores or two given" after "given"

to trace absolutely the relation between the amount of oil necessary and any one of the three factors, aeration, dilution and percentage of sulphide. The method, of course, would be to keep all conditions standard except the one particular condition under investigation and then vary that amount. Under mill conditions the relation may be considerably harder to distinguish, because, except in most exceptional cases, the ore varies from day to day through, it may be, considerable limits in percentage of mineral content or in the percentage

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of dilution. It is possible of course in the mill to keep the degree of aeration constant but these two conditions of percentage of sulphide present and dilution will vary quite widely without the control of the ordinary operator in the mill. There will unquestionably, however, arise cases in which the relation between the amount of water and the amount of oil required or the amount of sulphide matter and the amount of oil required can be distinguished in mill operations. Some of the figures that have been presented by the men from the different mills to date indicate that they are confirming this opinion, and while I have not the definite figures at present at hand to confirm from these mill sheets, I think that that can be—could be studied out. The amount of oil that can be disposed of in the process, that is the range through which you can carry the oil with a given ore and under given conditions is rather large, and in my discussion this morning I tried to make it clear that I was speaking of the required amounts of oil to get certain conditions. That is, if, with all our conditions constant, you had been working with a minimum quantity of oil to do the work and you increased the amount of sulphide in the feed, then in order to get satisfactory conditions it would be necessary to increase the amount of oil added; or in the case of the dilution, if, all other things being constant, you had been working with a minimum quantity of oil necessary to produce a certain result with a given dilution, and if you increased the dilution—that is the percentage of water—then it would be necessary to in-

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crease the amount of oil added in order to get the result that you had been obtaining before. And the same thing of course, in the case of aeration. It is true, moreover, that the condition has been presented by some of the previous witnesses that when they increased the quantity of oil that they added to the froth they decreased their agitation and they said that they did this in order to get good results. I think the explanation of that is that, not having varied the sulphide content and having more oil present, it was not necessary to do such a large amount of agitation in order to insure that the requisite amount of air bubbles for the collection of the sulphide material in the froth would be coated with a sufficient film of oil to serve their function. Consequently they decreased the amount of their agitation. And they further found that if they did not decrease the amount of agitatiion that they got what we may call over-frothing, that the froth overflowed the spitzkasten and ran all over the mill. I think the explanation of this is the fact that it is possible to stabilize the bubbles with a considerable smaller amount of solid material than is ordinarily the practice in the machine; that when they add the greater quantity of oil and thus coat a larger number of air bubbles, there having been some air bubbles coming through without an oil coating when the minimum amount of oil was used, the greater number of oil coated air bubbles each took up a smaller load of solid material, the load of solid material was sufficient to stabilize and consequently there was this increased number

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of air bubbles each with a sufficient load of solid material to stabilize it rising to the top of the spitzkasten and overflowing the spitzkasten. Therefore, they reduce the amount of agitation, reducing the number of air bubbles that were rising to the surface, loaded each one more heavily with sulphide material and thus reduced the over-frothing.

MR. SCOTT: You may cross-examine.

#### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 110. You have mentioned particularly experience in the mill of the Nevada Consolidated Mining Company at McGill, Nevada. How long ago was that?

A. 1910.

X-Q. 111. Did they use any flotation then?

A. No.

X-Q. 112. In what manner was the ore concentrated, generally?

A. Tables and vanners.

X-Q. 113. Water concentration?

A. Water concentration.

X-Q. 114. Were there slime losses?

A. Yes, sir.

X-Q. 115. Very considerable slime losses, were there not?

A. Quite considerable. I speak now with the viewpoint of an operator. I was not in a position of such authority there as to know the figures of recovery of the company.

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X-Q. 116. But they were constantly impounding slime tailings, weren't they, that were of considerable value?

A. That I couldn't say. They were passing the slime overflow through settling ponds, which would of course have the result of getting some of the contained values.

X-Q. 117. What kind of an ore did they have?

A. The ordinary so-called porphyry ore.

X-Q. 118. A lean copper ore?

A. Yes, with considerable iron sulphide present.

X-Q. 119. When did you last learn of their operations, from inspection?

A. In the fall of 1910.

X-Q. 120. So that you do not know that since then they have adopted flotation and are now getting very fine results?

A. Not of my personal knowledge.

X-Q. 121. And then the Montgomery Shoshone Mining Company. When were you there?

A. In 1908.

X-Q. 122. What kind of an ore?

A. Gold ore.

X-Q. 123. No flotation then I take it?

A. No.

X-Q. 124. When was your attention first called to flotation concentration of ores?

A. When the articles concerning it first began to appear in the mining periodicals.

X-Q. 125. About?

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A. I should presume that I became interested in that back along in 1912—probably 1911 or 1912.

X-Q. 126. Did you write or participate in the writing of an article which appeared in "Metallurgical and Chemical Engineering," volume 15, November 1, 1916?

A. I can't remember the particular date of its appearance. I think I can identify the article.

X-Q. 127. I show it to you?

A. Yes.

X-Q. 128. I read from that articles as follows: "The importance of flotation lies in the fact that it is primarily a "slimes process," by means of which the particles of valuable mineral too fine for efficient gravity concentration are saved with a high percentage of recovery. Recovery in the mills treating low grade copper sulphide ore have been advanced ten to twenty per cent by the installation of the process and similar increased saving can be accomplished by the same means in mills treating sulphide ores of zinc and lead." That is a part of the article that you published and read before the American Institute of Mining Engineers in September, 1916?

A. It was presented before them. I did not read it.

X-Q. 129. And you accept those statements as true today?

A. To the best of my knowledge.

X-Q. 130. I read from that article as follows: "(1) That water has a smaller tendency to displace air on the surface of sulphide minerals than on the surface of gangue minerals; (2) that the tendency of oil to dis-

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place air is greater at the surface of sulphide minerals than at the surface of gangue minerals; (3) that oil tends to displace water on the surface of sulphide, and that water tends to displace oil at the surface of gangue minerals; (4) that water displaces air more readily on an oiled solid surface than on a clean surface of the same solid; (5) that these tendencies towards displacement are due to the interfacial tension or pressure existing between the various substances and that the resulting action of this interfacial force is a manifestation of the tendency towards reduction of the total potential energy of the system. Wherever an increase in the solid-fluid surface will decrease the potential energy, such a change will occur." You accept those as statements which you today will advance?

A. Yes.

X-Q. 131. And following in this article is a description of an experiment to demonstrate the fact that water tends to displace air more ~~readily~~ rapidly from an oiled metallic surface than from a non-oiled metallic surface. Will you accept that as a fair statement of what you demonstrated in the article?

A. Yes.

X-Q. 132. What is the difference between adsorption and absorption?

A. Absorption is the taking into the mass of a substance—some other substance, and as ordinarily used I think it is considered that the substance taken in by absorption passes through and diffuses through the mass of the absorbent. I <sup>m</sup>ay use a homely illustration,

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of a sponge placed in water; the sponge absorbs the water. Adsorption is the concentration at the surface between two phases—physical phases—of some substance which is a contaminant of one of the phases, under the rule that in a mixture of two substances, that the substance which will tend to reduce the surface tension of the system will tend to concentrate or adsorb at the contact of the system with some other phase.

X-Q. 133. THE COURT: How does that apply to this question?

A. The question of flotation, when you have in the mass in the beater cells small globules of oil and small bubbles of air, when a particle of air and oil are brought closely enough together so that these forces which tend toward adsorption and which are rather small forces—can act, then the oil will spread itself over the entire surface of the air bubble within the pulp, because by so doing it can lower the surface tension of the pulp at the gas-liquid interface; the gas and the liquid being the two phases, and the oil the contaminant in the liquid, which tends to concentrate or adsorb at the interface between the two phases.

X-Q. 134. In testifying in regard to what you have called the agitation froth process, you have confined your description to the agitation in one vessel and separation of the froth in another as I understand it; is that right?

A. Yes.

X-Q. 135. You are aware, are you not, that the process is carried out with an agitator at the bottom

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of one vessel; air flowed in at the bottom of that vessel and the froth taken off at the top of the same vessel; that is known as sub-aeration; are you aware of that?

A. Yes, I have heard of it.

X-Q. 136. And then there is another variety, is there not, wherein there is no agitation in this vessel, but the air is broken up by flowing in underneath through a porous medium, and flows up, and the froth is taken off at the top?

A. Yes.

X-Q. 137. And referring to that, did you, in this article, state as follows:

"The principles involved in this method are the same as explained in the agitation-froth process. The only difference is in the method of introducing air. The result of this difference is that the bubbles in the pulp are much larger than in the agitation-froth method; they arrive at the surface less heavily loaded in proportion to their weight. The bubble films are therefore less viscous and the froth less persistent."

A. Yes, sir.

X-Q. 138. Now, in the description that you have given of the bubble action in connection with the oiled mineral, I have not exactly understood what was the condition of the submerged bubble carrying the mineral or the sulphide particles attached to it, before its emergence above the surface of the liquid. Could you describe the condition of that bubble submerged ~~with the condition of that bubble submerged~~ with the metal particles or sulphide particles attached to it?

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A. I think I can.

X-Q. 139. Please do so.

A. Of course that is something that is not capable, in the cell, of actual observation; but reason should lead to some such situation as this: (drawing) This represents a bubble in the mass of the pulp, and at some subsequent instant that bubble has met with a small globule of oil.

X-Q. 140. BY MR. SCOTT: Won't you please letter those points as you pass along?

A. Yes, I will do that. The bubble A, in the mass of the pulp B, having met a globule of oil, will become surrounded by a film of oil which is concentrated at the surface between the two phases, gas and liquid. The reason for such concentration is that by means of it the mass marked "B" can reduce its surface energy. The degree of concentration will vary from a maximum at the actual air surface to nothing or practically nothing at a distance away from it, and there will be present then, because that variation takes place through a very short distance—an interface or film, similar to the film or interface presented here between the oil and the water. The situation being on a much exaggerated scale, we might take the atmosphere of the room for the air of the bubbles, and the oil adsorbed at the air surface here and the water here, and here the point of varying concentration—or the place of varying concentration of the oil and water, from full concentration of the oil to full concentration of the water, being a very small distance.

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X-Q. 141. Will you say what you referred to in your answer; you did not describe it.

A. I refer to the red water and bubble experiment performed this morning. If we consider then, that this line (drawing) represents that interface, the line being marked C-D on my sketch, and at this side we have water and at this side oil, and if we consider, presented at that interface in some such fashion as that, a particle of sulphide mineral, and if we consider that that interface, the line C-D, is a fixed part of our system, and that the particle of solid matter is a moveable part of the system, then, due to the tendency of the oil to replace water at the surface of the sulphide particles, and due to the further fact that the line C-D here is fixed and can not move, then the sulphide particle itself must move, and the sulphide particle will move over into the oil. The reverse condition holds with the gangue particles. Here, assuming the line C-D or the plane represented by the line C-D, to be fixed, and the solid particle, the movable part of the system, then, due to the tendency of the water to replace the oil, in order to satisfy that tendency, the gangue particle must move into the water, and at that point you get the separation, so that you finally have then these particles of sulphide moving into the film—I will mark them "S"—moving in near to the air-liquid interface within the mass in the beater machine. I have marked this diagram No. 7.

MR. SCOTT: I offer this diagram which Prof. Taggart has marked No. 7 in evidence.

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Diagram admitted in evidence without objection marked DEFENDANT'S EXHIBIT No. 130.

X-Q. 142. Now, Prof. Taggart, is there such an adsorption as you have spoken of at the oil-water phase—is there not an oil-water phase there, too?

A. Yes.

X-Q. 143. Is there an adsorption at that interface?

A. Adsorption of what?

X-Q. 144. That is what I would like you to tell me.

A. I don't know of any particular adsorption there that is of any importance in the particular discussion. It is probable—it is true that if there is present in either the oil or the water any contaminant which, by adsorbing or concentrating at the interface between the

P. 3002, L. 18, insert "that there will be adsorption of that particular contaminant at that interface," after "face"

and have any particular effect on the operation of the process.

X-Q. 145. Now, that layer of oil which surrounds the hole in the water that the air makes—

A. The hole in the pulp, you mean, do you not?

X-Q. 146. Yes, the hole in the pulp; that layer of oil is a definite layer, distinct from the water, is it?

A. I have indicated here a zone of transition from the highly concentrated oil to the highly concentrated water, and I have drawn the parallel here to the colored water-oil test; assuming this as a section on a very large scale of an air bubble of which the atmosphere of

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the room here forms the air. You see there concentrated at the air surface, due, I grant you here, to the force of gravity, a layer of oil, and there is a layer right at this surface between the oil and the water, through which the concentration varies regularly from a concentration of all or practically all oil, less and less and less oil to a concentration of practically all water. There is no actual discontinuity there, but the distance through which that variation in the concentration takes place is so small as to look like a sudden transition to the naked eye. Now, a similar transition takes place at the surface of the bubble in the pulp.

X-Q. 147. Would you call that an adsorption layer?

A. Unquestionably that would be an adsorption layer between the two liquid phases.

X-Q. 148. When the bubble is then immersed so that it is merely a hole in the pulp filled with air, would you say that it has a film about it?

A. I should think that would be a question of the definition of a film. Speaking accurately, I should not; I should say that it had about it a layer of oil which has this property that I have been repeating, of varying its concentration from the greatest concentration of oil at the air-liquid interface, gradually tailing off, decreasing until you get to a maximum concentration of the water at a distance from the bubble.

X-Q. 149. In talking of the oil as you have in the last few answers, have you reference to an insoluble substance?

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A. I presume you mean by insoluble the word as it is applied ordinarily to what are called insoluble oils as differential<sup>ed</sup> from the so-called soluble oil?

X-Q. 150. Well, take it that way and explain it.

A: I should say that the difference there is merely one of degree, and not of kind. That same thing would occur whether I were describing soluble oils here or the so-called insoluble oils; the difference being that the layer through which you pass from maximum concentration of oils to maximum concentration of water would be somewhat thicker, and bearing in mind that that change takes place through <sup>such</sup> a small distance here that it is practically impossible to distinguish it with the naked eye, you would still have the working condition about as presented in the previous discussion.

X-Q. 151. Well, let us take the case of a completely soluble modifying agent—frothing agent—dissolved in the water; what will happen then in the submerged air bubble?

A. Are you willing to further qualify your answer by stating that the oil or soluble modifying frothing agent will lower the surface tension of the pulp if it concentrates at the air-pulp contact?

X-Q. 152. As I understand it, that is a characteristic of all frothing agents, that they lower the surface tension.

A. I just wished that to appear in the question:

X-Q. 153. That is your understanding, is it not?

A. That is my understanding. If, then, that agent will lower the surface tension by adsorbing or concen-

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trating at the gas-liquid interface, it will so concentrate and adsorb.

X-Q. 154. Now, under such a condition, the dissolved frothing agent is normally distributed throughout the whole mass of water and pulp?

A. Yes.

X-Q. 155. You agitate so as to introduce air, or you introduce air by any other means, and you get a bubble in the pulp?

A. Yes.

X-Q. 156. Now, what kind and degree of concentration do you get around the wall or surface of that submerged bubble?

A. A sufficient concentration to lower the surface tension of the pulp at the gas-liquid interface.

X-Q. 157. Now, when the metallic particle meets that kind of a bubble, what happens?

A. The same thing exactly as happened in the case represented on the blackboard, provided that there is enough of this so-called soluble frothing agent there to coat the ore particles in the froth with a sufficient film of oil to allow of the selection of the gangue from the sulphide.

X-Q. 158. Now, in order to get away from oils, which you have rather interjected into your answers—suppose we take acetic acid as the soluble frothing agent, which reduces surface tension and produces, under the use of agitation and aeration, metalliferous froth—you know it does that?

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A. I have not done it experimentally, I will take your word for it.

X-Q. 159. Isn't it a known fact among students of this subject that acetic acid will do that?

A. I have heard of it, but I have not seen it.

X-Q. 160. Well, upon that assumption you can go ahead and tell me what will happen; describe the condition of the concentration or the condition.

A. The acetic acid in this particular instance plays the part which has been ascribed to the oil in the preceding discussion, provided that the acetic acid will lower the surface tension of the pulp, if it concentrates or adsorbs at the gas-liquid interface. I have not looked the figures up on that, nor have I made any experiments on it, so that my answer is based entirely on general reasoning, as concerns the process.

X-Q. 161. I unfortunately selected a soluble frothing agent with the action of which you were not familiar. What soluble frothing agents have you operated with and are you familiar with?

A. I am not particularly familiar with the action of any of the so-called soluble frothing agents as opposed to the so-called insoluble frothing agents, Mr. Williams. My work to date has been most largely attempting to construct a theory and reconcile with that theory observed facts, and it has not yet extended to the point where I feel myself qualified to state from definite experimental data anything in regard to any such difference as I presume you are attempting to indicate.

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X-Q. 162. Phenol and cresol you know they are soluble frothing agents?

A. Yes.

X-Q. 163. And you know that they are present in wood tar oil?

A. Yes.

X-Q. 164. And coal tar oils?

A. Yes, I do. I know that from reading; not from analysis.

X-Q. 165. Is your knowledge such that you can give me any figures as to the actual concentration that would take place at the surface of an immersed air bubble in the presence of any dissolved frothing agent?

A. No, sir.

X-Q. 166. You do not know as a fact that the ratio of concentration is less than one millionth?

A. No, sir.

X-Q. 167. You don't know that?

A. No, sir.

X-Q. 168. Now, in the presence of a soluble frothing agent what happens to the metallic particle before it meets an air bubble?

A. It probably has adsorbed or concentrated at its surface some of the soluble frothing agent.

X-Q. 169. You put that forth, of course, as a theory?

A. As a theory.

X-Q. 170. And when that metallic particle meets an air bubble, just what happens?

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A. I should expect that some of the soluble frothing agents which had been adsorbed at its surface would adsorb at the air-liquid contact.

X-Q. 171. Then what happens to the metallic particle?

A. If the degree of adsorption at the air-liquid contact is sufficient so that the condition that I have represented in my diagram 7 obtains, then the sulphide particle will pass into the layer of higher degree of concentration of the so-called soluble frothing agent and be carried to the surface with the bubble.

X-Q. 172. And what holds it there in the rush and swirl of the pulp while being agitated?

A. This surface force of adsorption and the fact in that in that particular condition in the pulp the sulphide particle represents the condition of least possible potential energy of the mixture of sulphide particle, soluble frothing agent and concentrate at the surface of the bubble and water.

X-Q. 173. What happens to that bubble when it commences to emerge from the pulp?

A. Some of the soluble frothing agent—I suppose you are still talking of these so-called frothing agents?

X-Q. 174. Yes, the same ones.

A. Adsorb at the new air surface that is formed because by so adsorbing and by so concentrating it can reduce the energy of the system formed of soluble frothing agents, water and gas.

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X-Q. 175. And then as that bubble rises up out of the pulp what happens?

A. This process continues<sup>as</sup> the bubble emerges into the air, at the air surface there is a concentrated layer of the so-called soluble frothing agent, the concentration passing off toward the interior of the film and at the center of the film the concentration of the so-called soluble frothing agent is ~~past~~ and the concentration of water is greatest. From that point ~~one~~<sup>on</sup> the concentration of the so-called frothing agent increases until at the other gas surface the concentration is again a maximum.

X-Q. 176. That is to say, at the outside of the bubble you have a maximum concentration; at the inside wall of the bubble or the inside of the film of the bubble you have a maximum concentration and passing through the thickness of that wall, however thin it may be, you pass through these stages of maximum, minimum maximum? Is that right?

A. Yes, sir.

X-Q. 177. And where is the mineral, the metalliferous mineral product?

A. The mineral is wholly within the bubble, ~~the~~ film.

X-Q. 178. That is given as a theory?

A. No, that is an observed fact.

X-Q. 179. An observed fact as you showed it to me?

A. Yes, sir.

X-Q. 180. But I could not observe it.

A. Perhaps you are not accustomed to working through a microscope.

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X-Q. 181. Now you have showed it to me with an oil?

A. Yes, sir.

X-Q. 182. And that oil was, so far as we saw it there, insoluble oil, was it not?

A. Insoluble?

X-Q. 183. An insoluble oil, an oil that has not been dissolved?

A. I should not attempt to so define it from my observation.

X-Q. 184. Was that oil partly dissolved, that we saw under the microscope?

A. I think unquestionably so.

X-Q. 185. Partially dissolved and partially undisolved.

A. I think unquestionably so.

X-Q. 186. What kind of an oil did you use in that experiment?

A. In this particular case?

X-Q. 187. In the particular experiment that you showed me?

A. I would have to ask somebody from the Butte & Superior to say as to the oil. The phenomenon to be observed is the same with any oil so I didn't pay any particular attention to the oil that was used. If you care—would you like—

MR. WILLIAMS: I will take the statement of whoever put the oil in.

MR. SCOTT: Mr. Dosenbach.

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MR. DOSENBACH: The oil was mixture consisting of 70% fuel oil, 18% pine oil and 12% kerosene.

X-Q. 188. MR. WILLIAMS: Endeavoring to put the matter in language not scientific, perhaps, but more understandable to the lay mind: When you have oil, in the flotation process, the oil coats the metal, doesn't it, in the pulp?

A. I think that some of it, some of the metal in the pulp is coated. As I say that question of coating the metal in the pulp is purely a question—I presume you mean before the metal comes in contact with an oil coated bubble?

X-Q. 189. We will take that?

A. That is purely a question of chance. You have got a certain number of globules of oil in the pulp, emulsified there, an enormous number, millions or even billions would be needed to express the number. Also if I recollect correctly, a cubic inch of a sulphide subdivided into the size of the ordinary flotation process breaks up into something like three hundred million particles. Now, in a mixture containing millions of oil globules and millions of sulphide particles, the number of probable combinations of the oil globules and solid particles is of course enormous, and there are therefore an enormous number of chances for an oil particle and a sulphide particle to come together. If they do so come together the oil would tend to absorb at the sulphide surface by replacing the water. If, however, one of these particles should miss meeting an oil globule of course it would miss being coated.

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X-Q. 190. Now, turning to your diagram 7 and to the line that you have indicated CD. In the case of a soluble frothing agent, a frothing agent wholly in solution, to the right of that picture would be water containing soluble frothing agent dissolved in it, wouldn't it?

A. Yes.

X-Q. 191. What would be to the left of that picture where you now have oil?

A. The concentration of the soluble frothing agent to the left, and you will recollect that my line CD represented a line somewhere around in here surrounding the bubble, so that there is the so-called oil to the left of this line and the water at the right. The concentration of the so-called soluble frothing agent will increase as the air-liquid interface is approached.

X-Q. 192. And the upper of your particles marked "Sulphide" will be where with the soluble frothing agent?

A. There. And in the same position that they are are marked there.

X-Q. 193. And the thing that shields that metal particle from the air inside the bubble will be where?

A. This. The interface between the air and the liquid, and at that interface the oil will be most wholly—or the frothing agent will be most wholly concentrated.

X-Q. 194. And you present that theory without having any knowledge of the amount of concentration that takes place?

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A. Yes, sir.

X-Q. 195. And as to whether it may be a wholly negligible factor?

A. Well, it is not a wholly negligible factor.

X-Q. 196. You accept the term "selective action"?

A. As meaning what?

X-Q. 197. Oils and metals in the ore pulp.

A. As meaning that the oil has a tendency to replace the water at the surface of the sulphide particle and that the water has a tendency to replace the oil at the surface of the gangue particle, yes, sir.

X-Q. 198. Now, suppose we have a pulp in which acetic acid is dissolved?

A. Yes, sir.

X-Q. 199. Has acetic acid that same selective <sup>ity</sup> for metal?

A. It must have if the sulphide particle concentrates at the surface of the air bubble in a way entirely similar to the way in which it concentrates at the surface of the air bubble when oil is used as the contaminant rather than acetic acid.

X-Q. 200. And how about the gangue?

A. The same statement must apply.

X-Q. 201. That is to say, the acetic acid solution selects the metalliferous mineral for concentration at its surface and does not do so as to the gangue?

A. Whatever ~~absorbs~~ at the liquid-gas interface, when acetic acid is used as the contaminant, forms there a film which acts with respect to the sulphide in a way entirely similar to the way in which the oil acts

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when oil is used if, as I say, the sulphide concentrates at this gas-liquid interface.

X-Q. 202. Take such a substance as saponine in solution in water. Will that reduce the surface tension?

A. I do not know.

X-Q. 203. Will that adsorb at the surface of the metal?

A. I do not know.

X-Q. 204. Where, in your theory, is the selective action of air for metal utilized?

A. It is not utilized.

X-Q. 205. Discarded—You discard it?

A. Yes, sir.

X-Q. 206. Wholly?

A. Yes, sir.

X-Q. 207. Take soap, for example. That dissolves in water. That reduces surface tension, does it not?

A. Yes, sir.

X-Q. 208. Does that adsorb at the surface of a mineral when thus dissolved.

A. I do not know. It is not necessary that everything which reduces the surface tension of a liquid and thus adsorbs at the surface and aids in stabilizing a froth will also select a sulphide mineral from a gangue.

X-Q. 209. Why not?

A. I do not know. These are experimental facts, that there are certain substances which so adsorb at gas-liquid surfaces will select sulphide mineral from gangue.

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X-Q. 210. And are both these conditions necessary for froth flotation?

A. First that the—no, it is not necessary that the particle which selects shall also reduce the surface tension.

X-Q. 211. But is it necessary that there should be something to select and something to reduce the surface tension?

A. No. There should be something to select.

X-Q. 212. Well, what do you mean by that?

A. That there should be present something which will adsorb, or which will cause adsorption at the surface of some substance which will have a selective action for the sulphide as opposed to its selective action for gangue.

X-Q. 213. Isn't air such a substance?

^ P. 3015, After L. 19, insert "A. I don't know that from my own investigation."

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A. I have seen the operation at the Butte & Superior Mining Company's mill and at the mill of the Utah Copper Company.

X-Q. 216. During what period?

A. Recently, since I have come to Butte.

X-Q. 217. Since the first of the year?

A. Yes, sir, since I have come to Butte.

X-Q. 218. And all these operations that you observed were with what general proportions of oil?

A. I do not know. I do not know at Butte & Su-

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perior. I do not know what all the operations were at the Utah Copper. Some of them I know and some of them I do not. They were more or less varied.

X-Q. 219. I suppose you would not be able to recognize the difference between large and small quantities of oil?

A. That depends upon how large and how small.

X-Q. 220. Well, take below twenty pounds and above twenty pounds—take four pounds of oil to the ton of ore and then 22 pounds of oil to the ton of ore. You would recognize the difference at once wouldn't you?

A. I can't say, Mr. Williams, because my experience with these operations has been, as you see from my answer to the last question, rather small and I would not say. If you will say 200 pounds or 250 pounds, yes; I can tell that without any question.

X-Q. 221. Well, suppose we take an operation with two pounds of oil to the ton of ore, one tenth of one per cent. As I understand your theory the oil carries the mineral in the froth, is that right?

A. The froth carries the mineral; and the froth consists of oil and water and air.

X-Q. 222. Mighty little oil there, isn't there?

A. Yes. The bubble film, I should perhaps say.

X-Q. 223. Have you ever seen the concentrates that come from an operation of two pounds of oil to the ton or less?

A. Not that I know of.

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X-Q. 224. You are not aware of the fact that the oil has disappeared from sight and touch?

A. No, sir.

X-Q. 225. Now, when you announced three conditions which determine the amount of oil, the amount of the sulphide mineral, the amount of aeration and the dilution of the pulp, did you base that upon a study of recent operations such as you have described?

A. No, sir; that was based purely on reasoning, and, as I think I stated previously, some outside confirmation in mill practice, in the figures presented previously. I have not yet had time to go through those sufficiently thoroughly to make that an absolute statement, but the figures tend in that direction. It is very hard, as I think I said before, to sort such conditions out in mill practice, due to the fact that one of two conditions, or two of them, may be operating at the same time, and it is hard to segregate one from the other; but in such cases where two of the conditions do remain constant over any period, then the third is very plainly the determining factor in the amount of oil necessary.

X-Q. 226. As a matter of fact you put those forward as theories which seem reasonable to you?

A. No, I put them forward as explanations—as predictions of what must occur, from observation of other observed phenomena.

X-Q. 227. But they have not been subjected to the acid test of study of those conditions in the manner in

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which they should be studied before you could put them forward as rules?

A. Carrying all things constant and varying one of them, you mean?

X-Q. 228. Yes.

A. No, I have not.

X-Q. 229. You said in one of your answers that acid in the froth flotation process tends to adsorb at the gangue particles.

A. At the surface of the gangue particles.

X-Q. 230. Did you refer to any particular acid?

A. Sulphuric acid. That is the one principally used.

X-Q. 231. Does that imply that there is a reduction of surface tension by reason of that adsorption?

A. No.

X-Q. 232. Does sulphuric acid when dissolved in water, increase or diminish the surface tension of the water?

A. I believe that it increases it.

X-Q. 233. That is a well known scientific fact, is it not?

A. I have seen it stated recently in some books; I looked it up particularly in anticipation of the question.

X-Q. 234. The Chemical Calendar gives that, doesn't it?

A. Yes, I think so.

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X-Q. 235. A rather remarkable fact, that sulphuric acid, when dissolved in water, increases the surface tension of water, making it a rather unusual substance in that particular, isn't that the fact?

A. I did not read that.

X-Q. 236. Isn't it a fact?

A. I don't know as to that.

X-Q. 237. Now, in your article, of which I read portions to you; in case No. 2, sulphide gangue, water, oil and acid. You say "The addition of the acid has the two-fold effect of further lowering the surface tension and decreasing the adhesion ratio." That is true, is it not?

A. True reading, yes. I have learned more since that was written.

X-Q. 238. That was a mistake?

A. That was a mistake. It will be noticed, I think, if you look at the paper that the lowering of the surface tension by the acid—if you will recollect the experiment here, the question of lowering of the surface tension has not been emphasized as the important factor in the stabilizing of the froth.

THE COURT: I suppose your science is like law, always something to learn?

A. Yes, exactly, and this is rather a new branch.

X-Q. 239. MR. WILLIAMS: How would you popularly define this viscosity?

A. I think, as the resistance of two adjacent parts, both liquid, to the movement of one part past the other.

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X-Q. 240. Would tenacity be suggestive of the quality of viscosity?

A. Well, I should think that viscosity with that definition would be a sufficiently definite term to use.

X-Q. 241. Would you accept "tenacity" as somewhat illustrative of the quantity of viscosity?

A. No, I would much rather use viscosity. Tenacity has an entirely different meaning.

X-Q. 242. Do you know the methods that are used or that are perhaps the most usual methods used to measure viscosity?

A. No, sir; I think that one of the subsequent witnesses can probably give you the physical methods.

#### RE-DIRECT EXAMINATION,

BY MR. SCOTT:

R-Q. 243. Do you know of any instance, Prof. Taggart, in which a substance which has the effect of raising the surface tension of water understood to produce froth flotation and concentration?

A. In the Potter-Delprat process, which consists in the introduction into a pulp, finely ground, of hot sulphuric acid, and a stirring of that pulp, there arises to the surface and forms on the surface a froth, which, looked at under the microscope, is similar in appearance to the froth which I showed this afternoon; that is, it consists of a liquid film generally within which are the particles of sulphide, and as far as I have been

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able to see, those particles are contained as wholly within the film as the particles in this film that we had here. Sulphuric acid raises the surface tension, and we get conditions that are entirely similar to the conditions to the process using oil. The question, however, will come entirely under the general presentation, that there is some substance present within the contaminated mass which by absorbing or concentrating at the surface—at the liquid-air surface, lowers the surface tension, and which has the further quality of selecting the sulphide from the gangue. The bubbles then rise to the surface and notwithstanding the fact that these bubbles may have a somewhat higher surface tension than that of water, there is, nevertheless, due to the selective action of whatever the film is at the surface of the bubble, that the sulphide particles—There is present a film of solid matter which is sufficient to stabilize that mass long enough to allow the froth to be removed from the machine.

R-Q. 244. Can you draw any inference regarding the relative importance of the powdered ore ~~and the powdered~~ ore and the liquid frothing agent as a stabilizing substance from the fact that this Potter Delprat process can be carried out, notwithstanding the raising of the surface tension of the water by the reagent used?

A. It is my opinion that the stabilizing by means of the solid matter is by far the most important part of the process of stabilizing. I think that was

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well represented in the experiment this morning in which you saw that with plain water, at the water-air interface, the solid matter stabilized the film and made it act approximately as a solid, while at the air-liquid surface, when the solid matter was absent, and yet some of the soluble agent was present, there was no such stiffening of the film as to cause the surface to act approximately as a solid.

R-Q. 245. Could you tell a bubble film of the Potter process from one formed with oil, by examining them under the microscope?

A. Not if the oil was used in very small quantities. As you increase the quantity of the oil, of course it becomes more visible in the bubble films, and then you could; but I used in the particular experiment to which I referred, a galena-limestone ore from Joplin, Missouri, some small quantity of blende being present, and in that particular ore—working on the Potter-Delprat process, and working with a small quantity of oil, as limited a quantity as I could use and still get froth, and I did not measure the exact quantities—Then I could not tell the difference between the froths. It is not true that I had them presented to me, one and the other, without my knowledge as to which they were and attempted to tell the difference; but with the knowledge of the facts before me I could not distinguish any difference.

R-Q. 246. If the oil were used in something above the minimum quantities, would it be by reason of any

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difference in the structure between the oil formed froth and the Potter froth that you would distinguish them, or merely by your ability to see the oil as oil?

A. I think merely by my ability to see the oil and see the possible play of colors at the bubble surface, due to oil contamination.

R-Q. 247. As far as the structure of the film and the nature of the film goes, would there be any difference between the two, even though a large amount of oil were used?

A. No difference in character; merely the difference in the thickness of the oil layer.

R-Q. 248. I think this morning you stated, and also this afternoon, that it is not essential to this process that the sulphide particles be coated with oil; that they are very likely to become coated with oil, but that it is not essential, and you stated that—I am not sure whether you stated that it was not necessary to pre-agitate before sending the pulp to the Spitzkasten or to the machine provided with the Spitzkasten; but in view of that statement I will ask you why it is that they usually agitate it before sending it to the Spitzkasten?

A. I think there are two reasons probably. If you do not preagitate, then you do not get the emulsification previous to the passage of some of the pulp into the Spitzkasten—That is, you do not get as great pre-agitation as where you use a couple of preliminary agitators before the separating process. The re-

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sult of the lack of such pre-agitation is that some <sup>up</sup> of the oil in the pulp, which has not yet been taken by bubble surface<sup>s</sup>, floats and is therefore lost to the process; and furthermore, to get as complete aeration and give as good a chance for the sulphide particles to pass into the froth, were you not using this preliminary agitation, it would be necessary to add one or more Spitzkasten and agitators to the regular flotation machine. There are those two things, and probably the <sup>more</sup> ~~most~~ important factor is the one of conserving the oil,—not wasting it on the surface of the first Spitzkasten.

#### RE-CROSS EXAMINATION.

BY MR. WILLIAMS:

RX-Q. 249. I don't think that you have described the oil bubble carrying metal particles as it is above the surface of the liquid.

A. I attempted to, sir; I said that we had at the interior of the bubbles, air; surrounding that a liquid film, composed, in the case of the oil bubble, of oil and water; that at the air-liquid contact—and I speak here of the air within the bubble—there is a concentration of the oil—a high concentration of the oil, and as you pass toward the center of the film the degree of the concentration of the oil lessens and the degree of concentration of the water increases, until at the center of the film the water is at its maximum concentration. Passing from that point outward, the degree of concentration of the water lessens and the

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degree of concentration of the oil increases to the outer air-liquid interface, where the oil concentration is again a maximum.

RE-RE-DIRECT EXAMINATION,

BY MR. SCOTT:

R-Q. 250. One more question. Have you made such a study of the Potter-Delprat process as would enable you to advance an explanation of those processes corresponding to the explanation that you have given of the oil process today?

A. Well, I should say that the explanation was absolutely the same, except that I do not know what the particular thing is which concentrates at the air-liquid contact, and which has a selective action for sulphide mineral as opposed to the gangue. We suspected, when we first started, that that thing was a case of gas attachment to the particles, and we were very much surprised and rather dumbfounded at first when we examined the films under the microscope and found that they were, in as far as we were able to distinguish, the same films that we had been obtaining by the use of oil—in appearance.

R-Q. 251. You have never ascertained, then, what it is which brings about this selective action?

A. Not apart from the fact that the system tends to arrange itself—and this is of course good physics—in such an order as to present the least energy—as to have the least potential energy.

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RE-RE-CROSS EXAMINATION,

BY MR. WILLIAMS:

RX-Q. 252. Are you sufficiently familiar with the history of the subject to know that the Potter process won't work with slimes?

A. No, sir.

WITNESS EXCUSED.

PROFESSOR FREDERICK E. BEACH, a witness called on behalf of the defendant being first duly sworn testified as follows:

DIRECT EXAMINATION,

BY MR. SCOTT:

Q. 1. Please state your full name.

A. Frederick E. Beach.

Q. 2. Will you please state your qualifications for testifying upon the subject now before the court?

A. Well, I was educated at Yale University, and my undergraduate course was as a student of mechanical engineering. After graduation I spent four years, part of the time as an apprentice and part of the time as a journeyman machinist, and then for a few years I was a draftsman, and after that I returned to Yale University as a graduate student, and after three years' study received a degree of Doctor of

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Philosophy, and since that time I have taught there, and my present position and title is Assistant Professor of Physics in Yale University. My teaching has been, with very slight exception, in the department of the university known as the Sheffield Scientific School; that is, the scientific department of the university as compared to the classical department.

Q. 3. About how many years has your connection with Yale University as an instructor or professor covered?

A. As I remember it, I have had charge of classroom instruction—not as a mere laboratory assistant, but as a classroom ~~instruction~~, <sup>or</sup> since 1891.

Q. 4. I presume considerable of your time is given to research, as well as instruction?

A. No, not a great deal; my occupation has been more particularly with the teaching functions than with research.

Q. 5. Have you any connection with mining operations or mining interests?

A. No; personally, none.

Q. 6. How did it happen that you became interested in this flotation concentration process?

A. Well, it was a matter of conference between the different departments. The staff—the Faculty of the Hammond Mining Laboratory, that is, the so-called mining department of the university, had this problem there, to teach flotation, and flotation processes of mineral separation; and as no accepted explanation

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had been given, and it was regarded as more or less of a mystery, a request was sent over to the Physics Department, the Sloan Physics Laboratory, for some collaboration on a work of investigation to see if we could find out what the explanation for this particular phenomenon was.

Q. 7. Did you make some progress in that investigation?

A. Why, yes; after studying it for a number of months—I don't recall just how long, but 6 or 8 months—we felt satisfied that we had a true and satisfactory explanation.

Q. 8. Can you summarize the points in the theory you arrived at?

A. Well, stated in a very popular way, it might be something like this: To take examples of familiar separation: Suppose, for example, that you had particles of finely divided gold held more or less in suspension in water. Now, it is known that mercury—quicksilver—has a selective action on gold; it is popularly said that mercury wets gold. As a matter of fact, gold is soluble in mercury, forming what is called an amalgam. So that, to make a sort of hypothetical separation process, imagine that we had a lot of small mercury particles falling down through a pulp consisting of water and suspended gold particles; as these mercury globules touched these gold particles, the gold would stick to the mercury and would be carried down to the bottom. Of course there is not any such actual

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process carried out; the actual selection of the gold particles by mercury is carried out in a different way practically, <sup>in</sup> the amalgamation process.

Now, to continue our imaginary picture, suppose that these little globules of mercury were blown full of air, so that they were mercury bubbles, and suppose that they <sup>were</sup> let in at the bottom of the vessel, <sup>were</sup> they would rise up through the mass, the little sheets of mercury on the outside of this bubble coming in contact with the gold particles would carry them up. We should have the elevation of the gold amalgam to the top of the surface. That is a picture that we could have in our mind of how we could separate gold by the aid of the selective action of mercury.

Now, we have a somewhat similar case in regard to sulphides and oils. It is known—I think it is acknowledged by everyone—that oil wets sulphides—and when I say sulphides I mean in general, metallic ores, or ores having metallic lustres; I do not specify sulphide as a particular case—Oil wets sulphides, and the sulphides adhere to the drops of oil. Suppose we took an amount of dense oil and let it fall down through a pulp, which is water containing a lot of sulphide particles in suspension, and that these drops of oil were heavy enough—I mean if the density of the oil were near enough to unity, or a little more than unity—as they dropped into the water surface they would fall a certain distance, and as they fell down, if they came in contact with any particles of

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sulphide they would carry them down to the bottom of the vessel, provided the density of the oil was greater than the density of the water. This is the analogy of the mercury drops carrying the gold down.

Now, to reverse the case, suppose we take out the interior of the little drops and fill it with air so that it is a kind of balloon except that the envelope of the balloon is oil or an oily film, and allow these oily balloons, so to speak, to rise up through this pulp to the surface. The sulphide would be above the surface, it would be elevated by these little balloons which they stick. Now, that is the mental picture that we formed of what actually happened in the flotation cell, after we had examined the process. Of course that does not account for all the details. I have it in mind a little bit later to point out the accepted scientific principles which bring all the processes of the flotation cell into harmony with the accepted facts or principles of physics. That is just a preliminary sketch of our idea of how flotation occurs.

Q. 9. Would it be in line with your plan of explaining this to state the particular principles or facts that you established?

A. In order to explain how this thing comes out or occurs it would be necessary to establish on an experimental basis certain facts: first, the fact of the selective adhesion of oil to a metallic or sulphide particle; second, it would be necessary to establish the existence and variation of surface tension; thirdly, we

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ought to establish the fact or the essential condition for a standard bubble film. These are essentially experimental facts. Now, fourth, we will make use of what is called the principle of minimum potential energy. The potential energy of a system tends to a minimum. In order to have a satisfactory explanation which would be accepted by the scientific world, these facts must be established. The principle, I suppose, is not subject to question.

Q. 10. How do you proceed to demonstrate the selective adhesion of different liquids for a solid? And, if I might make a suggestion, if it occurs to you as we go along, I suggest that you make use of the simple experiment that we started with, whenever an analogy occurs, I think it would help us; that is to refer back to the mercury bubble or the oil bubble whenever occasion arises.

A. Well, we are presented first with the question: Do different substances behave differently toward each other? Does one liquid wet a substance more than another liquid? And is there any way of making this quantitative? That is, I mean is there any way of saying that one liquid wets another twice as much as the first? That is the first problem that presents itself to me. In the flotation cell there is evidently some difference in the action of the liquids involved on the sulphide than that on the quartz. Now, can we exhibit or demonstrate in any way, apart from engineering processes, commercial processes, the fact

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that these liquids do behave differently with respect to these substances? Will one—we will resort to some very simple experiment. Take a perfectly clean plate of glass and put on it a drop of essentially pure water. Instead of this drop standing in a heap, it will flatten itself out and spread for a very considerable distance from the point which was initially touched. Now suppose you take the same water or a drop from the same sample of water and put it on the leaf of a familiar vegetable, cabbage, it will be observed there that this drop does not seem to spread out. In popular language without any attempt to make this a quantitative statement, one might say that water wets glass but does not wet the waxy vegetable surface. That, however, is not quite satisfactory to the physicist. He wants to know: How much does the water wet the glass? Twice as much as it does the cabbage leaf? Or is it 100 times as much? I do not know of any book in which that answer has been provided. Another familiar example of the selective action or a selective adhesion of liquid for solids can be seen in the case of mercury. If a drop of mercury is placed on the surface of glass, if the drop is relatively small, it will gather itself together in a globular form. If a drop of mercury is put on a gold watch case, the mercury will flatten itself out and spread over very much as the water did on the glass surface. There is evidently some intimate and essential difference in the behavior of substances with respect to each other. In

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popular language it is said that mercury wets gold but mercury does not wet glass. That is not very satisfactory. In fact it is not altogether true and if the court would permit me I would like to show a simple experiment which will—I mean I would like to draw a figure to illustrate a simple experiment which I have often tried before classes to indicate that mercury does wet glass. It is simply a question of degree and not a question of difference in kind. Suppose that represents a horizontal surface of glass and you take—

Q. 11. (Interrupting.) Professor, might I suggest that as you go along you letter everything so that when we have it here we can follow your illustration?

A. "G" represents a horizontal glass surface. And if we put upon that a drop of mercury ("M") that mercury will ultimately assume a shape something like that (indicating). I intended that the upper surface should be level. The thing to which I wish to draw attention is that at the point which appears to be the point of contact of the mercury with the glass, the tangent of that curve makes an angle between the glass and the tangent of roughly something like 135 degrees. I do not mean to say that it is always that, but it looks something like that. This angle on this side might be 45°. Now, suppose we vary our experiment indicating the contact of mercury and glass in this way. Suppose we take a tube and on the end

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of that tube we blow a little glass bubble or sphere (S). "T" represents the tube of glass; "S" the sphere which has been blown at the end of it. We will assume we make use of the convex surface of glass. Now, suppose we lower that down until it touches a horizontal surface of mercury. "H" is the horizontal surface of the pool of mercury (M). Externally it will be observed that this mercury surface is not level, as we get very close up to this sphere, but that it will rise above the hydrostatic level of the mercury, and we shall have the condition of things which was really present here, namely, that the angle between the tangent, the liquid surface and the tangent, the glass surface is again something like  $135^{\circ}$ . That is to say, the same condition of things occurs there as occurs here. But when you look at this diagram with the mercury rising up to meet the glass you will be convinced—when you look at that I say you will be convinced that mercury does wet glass. It sticks to it, adheres to it. Otherwise, it would not rise above its horizontal level. So, it is not true to say in such broad language that mercury does not wet glass. It is simply a question of degree, how much it wets it. Now, that is the first problem that is presented to us to find out how much these different liquids, oil, water, alcohol, acetic acid, other things, wet sulphide compared to the amount which they wet quartz or calcite or other gangue materials.

Q. 12. Before we forget it I would like you to

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mark the diagram. You might mark it diagram No. 8 with your initials.

(Witness marks diagram.)

MR. SCOTT: We offer this diagram in evidence.

MR. WILLIAMS: No objection.

Diagram admitted in evidence and marked DEFENDANT'S EXHIBIT 131.

WHEREUPON an adjournment was taken until 10:00 A. M. Thursday, April 26th, 1917.

Thursday, April 26th, 1917.

FREDERICK E. BEACH resumed the stand for further

DIRECT EXAMINATION

BY MR. SHERIDAN:

MR. SHERIDAN: If the court please, I would like to make a request this morning. We have some lantern slides of those pictures showing the different forms of bubbles and different froths with different varieties and kinds of oils. Now, it is not going to be very agreeable to show these in the daytime, either to the court or counsel; and if the court will give us an evening session, any evening, beginning, say at eight o'clock, it will probably take an hour and a quarter to an hour and a half to show them. I think it will be very instructive. A photograph looks flat while

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a lantern projection will look very clear. We want ~~to offer~~ them in evidence, but we would like to show them as we offer them.

THE COURT: What are these?

MR. SHERIDAN: Lantern slides of those photographs you saw. We have the lantern and the slides. Any evening that will suit the court and counsel.

THE COURT: All right, some evening before you get through.

MR. SHERIDAN: Most any evening. We can make it tonight or tomorrow night or any evening that will suit you.

THE COURT: Well, unless you have some special reason, next week.

MR. SHERIDAN: No, no special reason.

Q. 13. Now, Professor Beach, if you had not finished, will you kindly continue?

A. I was discussing at the close of the session, some methods by which we could judge quantitatively of the degree of wetting of a solid by a liquid. Now I satisfied myself that if we put a drop of a liquid upon the clean surface of a solid, the way in which this drop heaps itself up is an indication of its degree of wetting. If I may have a sheet of paper on the blackboard I will endeavor to illustrate what I mean. Suppose that that represents a clean surface of aluminum (A1.) and suppose by means of a medicine dropper you put upon that a small drop of water. By "small drop" I mean two or three millimeters in diameter. Then I find that that drop heaps itself up in some

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such way as that and the angle between the tangent and the surface of that side of the horizontal measured around there, this angle in most of the text books is called the angle of contact; but if you will permit me we may perhaps change that designation here. Let us call it the angle of repose. This is a heap of water and it finally seats itself so that it has a certain angle toward the horizontal surface. I find by referring to my notes of some measurements that I carried out upon this, that that angle, call it "theta" was  $85^\circ$ , with a variation either side of something like  $1^\circ$ . This was water and this was an aluminum surface. I tried a similar experiment, putting on it a drop of oil, for example oleic acid, and in that case—

Q. 14. Will you mark that "Oleic acid" please?

A. (The witness marks the word "Oil"). In general a drop of oil does not heap itself up in the way that the water does, but flattens itself out. I do not happen to have in my notes exactly what that angle was, but it was very small. Now, we judge of the degree of wetting, or the intimacy of the contact, the adhesion of the oil to the aluminum compared to the adhesion of the water to the aluminum by this angle that I have called the angle of repose. So here, we have a way of testing or examining what has been called the affinity of the liquid for the solid or the degree of wetting of the solid by the liquid.

THE WITNESS: I would like to call now for the chart which Professor Taggart showed in his testimony yesterday.

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Q. 15. Are you through with that chart there; if you are, kindly mark it "Beach diagram No. 9".

A. I have marked it "Beach diagram No. 9".

MR. SHERIDAN: I offer the diagram in evidence.

Diagram No. 9 admitted in evidence and marked DEFENDANT'S EXHIBIT 132.

(Taggart diagram No. 3, defendant's exhibit 126, handed to witness).

THE WITNESS: In the experiment which was shown to the court yesterday and of which this is a diagrammatic representation, we observe that the oil heaped itself up; that there was a very small portion of the surface of the quartz in contact with the oil, the oil being immersed in water; on the contrary, there was a considerable degree or area of contact with the oil and the galena. Here we have, then, of the principles which I have enunciated, experimental evidence, using different substances, different kinds of gangue, different kinds of sulphide and different kinds of oil, a means of judging how good this oil is in selecting the galena, and how good the quartz will be in rejecting the oil that is setting in the water. I will return to this discussion after having announced and explained certain other facts. This was the first one of the three facts which I propose to discuss, namely, the selective adhesion of a liquid for a solid.

Now, the next fact that we need to consider is the question of surface tension, the existence, and the possibility of varying surface tension. Every liquid

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surface behaves as if it were under tension; it behaves in some respects like a stretched elastic membrane; this, however, is only a way of looking at it. The thing that we actually observe is that when the constraints are removed, the tension is relaxed. It is merely a mental picture. We do not say it is actually under tension, but it behaves as if it were under tension. This is a well known and accepted and undisputed fact.

Now, I want to introduce another way of looking at this phenomena. I want to show that every square centimeter of any surface has associated with it a definite amount of energy, which is numerically equal to the surface tension, and this will be a little more helpful way of viewing the phenomena for our purpose. Considering any body, and imagine that it consists of two parts. Those parts are not separated at present; those are tied together and held there by a very strong force. It would take a pull of many pounds to separate those two parts of the body. Those forces are called the forces of cohesion; in other words, in order to separate those by pulling them apart, we have got to do a considerable amount of work upon the body. Now, after those parts have been separated, that energy is regarded as residing in the body in the surface produced by separation; for, if we were to bring these parts together close enough, in sufficiently intimate contact—not experimentally, but theoretically, they would unite. In the case of certain substances such union does take place. I am told that in ship-

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ping fine plate glass it is quite necessary to have sheets of paper or something between them; otherwise they are likely to weld together under the influence of the pressure. If we were to take two flat surfaces of lead and push them together, even with my hands, the cohesion would be shown to a certain degree, and I would have to pull a small amount in order to separate them again. I simply have got back a certain amount of this energy if I allow the surfaces to reunite.

Now, another way of looking at that is this: that whenever we produce a new surface, we have added a certain amount of energy, and when we allow that surface to disappear by a complete union, we get the energy back again. It is not very obvious in the case of solid bodies, but in the case of liquid bodies it gives rise to important phenomena, the phenomena of surface tension.

Now, I want to show that the measure or the numerical value of surface tension is numerically the same as the surface energy, and in order to do that, I will draw another diagram. Suppose I have two parallel wires. One of these wires I will designate by the letter "M" and the other wire by the letter "N". Suppose I put across the first pair of wires another wire which I will designate by the letter "R". Now, suppose that I put, up close to this wire, a fourth one which I will designate by the letter "S". Now, upon these two wires which are practically in contact, suppose I put a soap solution, so as to form a film between

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those two wires and then, taking hold of the wire "R" and the wire "S", I separate them by a certain distance, which distance I will call "L". In order to do that, and in order to hold that in this position which it is to retain here—this rectangle being covered over with a soap film, and the soap film tending to contract—in order to keep this film stretched I must exert in that direction a force, which I will call "F".

Q. 16. Will you letter that wire which you have last indicated?

A.  $S_1$ . The new position of the wire "S" is called  $S_1$ . You must exert on the other edge of this film an equal force, F. We will also, if you please designate the distance, between the wire M and the wire N, that is the breadth of our soap film, by the letter b. In stretching out this film we have done a certain amount of work which we may write in this way, " $W$ ".  $W$  represents the work done by the force F in moving the wire S from the position S to  $S_1$ , and the work done is the force F multiplied by the distance 1, which the wire moved. Now, consider the area which was inclosed there. The area of this film, the length 1, multiplied by the breadth b. But in a solid film we have two surfaces, an upper surface and a lower surface and each of these liquid surfaces has a liquid tension so that the total area involved in this particular experiment is the area of our surface  $1 \times b$ , and the same area below. So, in order to get the work done per unit area of all the surfaces involved we must divide by  $2A$  and, substituting the value of A, we

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have  $F1$  divided by  $2b \times 1$ , or cancelling out the letter 1, we have  $F$  over  $2b$ . That is to say, the force required to maintain this film stretched, divided by the total length of the film involved, which is the length  $b$  on the top side and the length  $b$  on the lower side. Now this force per unit is what in all text books is called the measure of the surface tension and will be designated by the letter  $T$ . This very simple equation shows that the work done per unit area is numerically the same as the surface tension. Then in an ordinary soap solution, a fairly dilute soap solution, I suppose that the surface tension is numerically about 27 dynes per linear cm. and that numerical value can easily be stated as 27 ergs per square centimeter. So, according to the kind of problem that we are discussing we may either think about the forces that are involved or we may discuss the amount of energy which is associated with both areas of the surface.

Q. 17. Will you kindly mark that diagram "Diagram No. 10"?

(The witness marks the diagram "Diagram 10.")

MR. SHERIDAN: We offer the diagram in evidence as Beach Diagram No. 10.

MR. WILLIAMS: No objection.

The diagram was admitted in evidence and marked DEFENDANT'S EXHIBIT 133.

THE WITNESS: I would now like to state one

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or two facts in regard to surface tension or interfacial tension, that this tension depends upon the nature of the substance on either side of the interface; depends upon the temperature; it is the same in all directions in the surface; it is independent of the thickness of the film when that thickness exceeds a certain minute value. Now, if we may return again to the relation of the drop of oil upon sulphide and a drop of oil upon quartz we could get some interesting and important relations which will be used in further discussion. Let us consider first the drop of oil upon the sulphide. This horizontal line will represent the upper face of sulphide. Suppose that we place upon that sulphide in the presence of water, a drop of oil. Suppose that this region here represents water. These are the conditions of the experiment as they were tried in the test yesterday. Consider that point which is just at the edge of the drop of water in the water. There are meeting there three surfaces or boundaries, the sulphide—oil surface, and in that interface there is a different amount of energy or interfacial tension which I will represent by an arrow and I will letter it  $T_{so}$ . That means the tension in <sup>the</sup> boundary between the sulphide and the oil. In the water-oil interface there is another tension which I will designate as  $T_{ow}$ . In the boundary between the sulphide and the water at this interface there is another surface tension which I will designate by  $T_{sl}$ , which subscription one refers to the medium immediately above the

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sulphide. Now when that drop has come to rest that particle may be regarded as in equilibrium under the action of three forces. If we call this angle of repose here by the letter theta, then the position of equilibrium may be written in this way, that the pull toward the left, which is represented by  $T_{sl}$  is equal to  $T_{so} - T_{ow}$  times the cosine of theta. The cosine of theta giving merely the horizontal component of this force. Now, looking at this equation,  $T_{sl}$  is necessarily greater than  $T_{ow}$ , because  $2s_1$  is equal to  $T_{so}$  plus something else. In other words, the surface tension out here is larger than it is at that point. In other words if we could, in any way, cause that surface tension to diminish then this point would be drawn farther and farther out. Then we see the degree of intimate contact of one liquid for a solid means a small interfacial tension. These are conditions which we have in the case of the oil upon the sulphide, discussed in terms of the force. Now I have shown that these tensions are the same thing as the energy associated with each unit area. By the principle which may be discussed further I have stated the potential energy of any system tends to diminish. We have here a relatively larger surface energy than that there. Now, by cutting out some of this surface we diminish the surface energy of the system, so in this particular case the area covered by the water, viz.,  $A_{sl}$  tends to diminish with respect to the area covered by the oil ( $A_{so}$ ). Our experimental facts have now been stated

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in language which will be very useful to us. When you put a drop of oil upon sulphide under water, the area covered by the water tends to diminish; the area covered by the oil tends to increase.

THE WITNESS: Now, obviously, if we are using small particles of sulphide, the greatest possible area that can be covered by the oil, of sulphide, is when the body is within the material of the oil.

Here, then, we have stated in definite scientific language a fact which is illustrative of the flotation process, namely, that the sulphides tend to bury themselves within the material of the oily substance.

Now, suppose we apply this same reasoning to the drop of oil on the quartz. I will number that diagram "Beach diagram No. 11."

MR. SHERIDAN: We offer in evidence the diagram marked "Beach diagram No. 11."

Said diagram admitted in evidence and marked  
DEFENDANT'S EXHIBIT 134.

THE WITNESS: Suppose next that we illustrate the case of the drop of oil upon quartz. This horizontal line which I have drawn represents the upper face of the quartz surface. In the experiment yesterday a drop of oil was seen to take a shape something like this. This medium above it and outside of the oil is water. We go through precisely the same steps of reasoning as before, considering a particle of oil at that point. The angle which I have called the angle of repose—the

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angle of the tangent at that point that it makes with the horizontal surface, in this case I will designate that as phi. Here we have a tension between the boundary of the water and oil called  $T_{ow}$ . In the boundary between the quartz and the liquid above we have another tension represented by the letter  $T_{ql}$ ; and at the boundary between the quartz and the oil we have another tension, which I will designate  $T_{qo}$ . These three forces I will shade so as to make them clearly conspicuous. The difference of equilibrium between these three forces is this:  $T_{qo}$  is equal to  $T_{ql}$  plus  $T_{ow}$  times Cos. phi, from which we draw the important conclusion that  $T_{qo}$  is greater than  $T_{ql}$ , because it is equal to  $T_{ql}$  plus something else.

Now, as the surface tension is the same thing as the surface energy, we see that the surface energy of the oil-quartz surface is greater than the surface energy of the boundary between the surface of the material  $Q$  and the region which I have called 1. Now, as this potential energy tends to a minimum, the surface having the greater potential energy will tend to diminish; in other words, the area of the surface  $Q_0$  will tend to diminish with respect to the area  $Q_1$ ; that is to say, this drop of oil, when it is put on a quartz surface tends to draw in together; it is as if you had the water surrounded by an elastic skin; the greater the tension there is in this lower surface, the more it will gather it in together. It is the contrary or converse case to that we had before, where you diminish

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the tension of the surface and the thing tends to let go or spread out.

We have now established these two things, that the area of a quartz-oil surface tends to diminish; that the area of sulphide-oil surface tends to increase; in other words, if you have particles of quartz in the vicinity of oil and water, the water surface grows larger and the oil surface grows smaller; that is, the quartz finally takes up a position within the water. Similarly the sulphide takes up a position within the oil. This thing was stated yesterday by Professor Taggart, and after having marked this diagram I will ask if I may again refer to his testimony, using the diagram which he put on the board.

Diagram last marked Beach diagram No. 12.

MR. SHERIDAN: I offer Beach diagram No. 12 in evidence.

Diagram admitted in evidence and marked DEFENDANT'S EXHIBIT 135.

(Defendant's exhibit 130, diagram 7, handed to witness.)

A. Professor Taggart's diagram represents a vertical boundary between oil and water. This particle is one of sulphide, and this particle is one of gangue. Now, by the principles which I enunciated and rested upon a secure experimental and rational foundation, lead exactly to the results as stated yesterday. The

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surface energy of that portion to the left of the line "CD"—

Q. 18. The portion of what, professor?

A. The portion of sulphide in contact with the oil —has a smaller surface energy than the sulphide in contact with the water. Now, by the principle of potential energy, it tends to a minimum. When a particle is wholly immersed in oil, the total surface energy is less than when it is partly in oil and partly in water. Similarly, in a particle of gangue, the surface energy of the tension of the gangue to the left of "CD," namely that portion wet by the oil, has a larger surface energy than the portion of the gangue to the right of "CD," namely that portion which is wet by the water. Now, since the total potential energy of this system tends to a minimum, the gangue will move towards the right or into the water. Here we have shown how the selective wetting by liquids of different solids may result in their differential separation in the presence of water, oil or other selecting agents.

I mentioned there were three facts upon which my explanation of mineral flotation in the agitation froth process is based; the three facts are the selective adhesion of the different substances, the existence and variation of surface tension. I have discussed the existence of surface tension, and I wish now to say a word about the variation of the surface tension. In the experiment shown by Professor Taggart in which a drop of oil was placed upon the clean surface of water, a neighboring

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chip—I mean a chip at a point near to the point upon which the drop of ore fell—this chip was seen to jump sidewise, indicating that where the oil touched the water there was a considerable diminution of surface tension, due to the concentration of the oil, or adsorption of the oil at the surface. This variation of the surface tension certainly plays some role—a fairly important role—in the production of stable films. I think I had better discuss that in order to make it clear, by the aid of a diagram.

Suppose we take a chemically pure substance—say, water as pure as we can get it, even though we have a film of water upon a wire ring, or even if we have a bubble on the surface of the water, it only lasts for an instant. If we use water which has been contaminated, which contains something different from the water, we can produce a bubble or a film which will last for a long time. I wish to explain how this is brought about.

Suppose that these lines represent a thin film of water bounded by air on either side. Suppose that the film is held at the top, and that a certain small force or weight was applied at the bottom, which I will call "F". If this force "F" is less than 75 dynes per centimeter, then the surface tension or the tensile force of this film would at least theoretically support the weight. If, however, the downward pull was greater than that, the film would stretch, thereby becoming thinner and thinner. Now, suppose that the thickness exceeds a very minute limit, there is no change in the tension of the surface. If we

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are to have a water film upon a ring, and hold it in a vertical position, under the influence of the weight, the water would gradually drain down toward the bottom, the upper parts of the film would have to support a greater, gradually increasing weight, with the result that it will gradually thin out a little more and more. There is nothing to prevent this thinning; there is no counter balancing force greater than the surface tension, and the thinning is soon brought down to the point where the bubble film will break. It is a very homely illustration, but it is very much like taking some soft gum, like chewing gum, and pulling it down; it stretches out, and as the cross section of this thread becomes thinner and thinner, finally it breaks. Now, in order to get a stability in a condition of this sort, we must have something different. I hold in my hand an elastic band. Now, suppose I stretch that elastic band. As I pull it down it becomes thinner and thinner. But I also notice that the force of restitution, the elastic force of the band, becomes greater and greater. This is the so-called Hook's law of elasticity. In proportion as the force acting upon the elastic body produces a greater stretch, by so much does the force of restitution increase. So that, in the case of this elastic band, if I hang on it a weight, it will settle down to a certain place, where the backward force, the resilience, or the force of restitution of the elastic band is equal to the weight. Now, how can this happen in a film of any sort? Say a film made with a soap ~~of~~ solution. Let this portion of the diagram rep-

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resent a film made of soap solution. Suppose now that we stretch this film out; what will happen? Well, it is first necessary to assert that whereas the surface tension of the pure water was about 75 dynes per centimeter—I am speaking in round numbers—that the soap solution, under exactly the same conditions of temperature and surroundings, will have a value of only about 27 dynes per centimeter. Soap—the particles of soap when they get into solution or mixture in the water affect the surface tension; they tend to diminish the surface tension; that is to say the surface energy of the soapy water is something of the order of one-third as much as that of pure water. Now, as this potential energy tends to a minimum, the more soap that you can get—the more particles of soap—I mean microscopic or molecular particles of soap that you can get into this surface layer, up to a certain limit, the more will the surface tension diminish. Now, that diminishes down to about one-third of its initial value for pure water, and there the process no longer proceeds further. So we start with a film which has less tendency to contract. We have a strong contractile force in pure water and a much feebler contractile force in soapy water. Now, that of itself will assist in the durability of the film. The stronger the surface tension the more difficult it is to make a bubble. For instance, it is easier to make an independent bubble of water than of mercury, for the reason that the surface tension of mercury is somewhere in the vicinity of four or five hundred dynes per linear centimeter. In the

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first place you can make this film and it will not have so much contractile force. Secondly, the soap which has gone into the solution tends to increase the viscosity; the mobility of the film is less; the particles of the film do not move with respect to each other so rapidly; but more important than all is this, that we have a means here, just as we had in the rubber band of stiffening the thing up when it gets too thin. Suppose that I represent by these dots little particles of soap which are in that region; suppose that there were ten of those dots or particles, to fix our ideas. Now, imagine that I have stretched this upper portion here out.

Q. 19. Will you mark that portion, professor?

A. I have marked it with a small "a". Suppose we fix our attention upon this portion, small "a", for the soap film, and suppose under the influence of an external force this is being gradually thinned out. I think you see now that these particles which are distributed through that layer, have now been scattered or spread out so that they extend through a longer portion or a larger portion of it; that is, the number of particles in an area "B", equivalent to the original area "A"—that surface is now much less—say five. What happens? When there were ten of those particles there, the surface then—the surface tension then was 27; when I have only five particles there the surface tension returns to a condition more nearly that of pure water. The surface tension will be larger then in proportion as the number of these particles thins out. Then as your soap film

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gets thinner and thinner, it has more and more elastic force, just as this rubber band did, and so we have the condition of a stable soap film, which is why a soap film will last so long. I have seen soap films that would last, stretched on a ring, for one or two hours, and I have never seen a bubble in pure water, if I formed it last more than a fraction of a second.

Q. 20. Will you kindly mark that diagram #13?

A. No. 13.

Diagram marked DEFENDANT'S EXHIBIT 136, and admitted in evidence.

I have now discussed sufficiently the three facts, experimental facts of physics upon which the explanation of flotation process rests. If the court please, just for the sake of the label, I might refer to these as the Beach-Taggart explanation, to define it from other explanations. I have shown that different solids have selective adhesion for different liquids; I have discussed the experiments as to the variation of surface tension and shown the conditions for a stable film. The chief factor, probably, in the stabilizing of a film is the increase of viscosity. Suppose the increase in the viscosity in a solid solution is not relatively great. The chief factor there is the variation of the surface tension, but in some other case, for instance in a Saponine solution, the change in the surface tension is not so much from other water as it is in solid solution, but the increase in the viscosity is very great. The increase in the viscosity of

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a liquid surface, due to the presence of fine particles was shown yesterday by Prof. Taggart experimentally. And, if the court pleases, I would like to say one word more about the principle of minimum potential energy which is an important one in the discussion of physical problems. If we are dealing with an elastic band it is very convenient to discuss the forces which are involved. We can see the points of attachment and we can get at the stretched portion to measure this force. But there are certain other cases where it is very difficult to form a picture of this force. For instance, if we have a reservoir of compressed air, we know that the air exerts a certain amount of force upon the containing envelope, but we do not always care to localize the force. We speak of the pressure of the system. If we are dealing with electrical phenomena, if for example I were to electrify a rubber rod, and bring it near a feather or a small piece of paper, we should find that the paper seemed to be attracted to the electrified rod, but we can not see the medium by which these forces are acting. In cases of that sort it is very much better to discuss the energy relations. So, as in the case of compressed air, we do not speak of the force of the air as much as we do of the pressure of the air. So, in dealing with electrical conditions we do not speak of the force as much as we do of the potential energy of the system. For example, in an ordinary trolley system. I do not happen to know what may be here, but in my own home at New Haven, the trolley wire has a certain amount of potential energy

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which is greater than the potential energy of the rails by an amount which is called 500 volts energy per unit charge. And we say that the electricity runs from the higher potential to the lower,—body at the lower potential. It is the exact analogy of the pressure of the air in the tank. The air flows from the point of greater pressure to the lower pressure. The air goes from the place of the higher potential energy to the place of the lower potential energy. The electricity flows from the places where it has high potential energy to the place where it has lower potential energy. Now, to top off my conclusion, that is, the discussion of the flotation problem, we are having particles move from the place of greater potential energy to smaller potential energy; so, we have to discuss the specialized or localized force, if we find that in a certain position a particle has less potential energy than it would have in some other place, that is the place into which it will move automatically, or by itself. For that reason we have contaminants adsorbing into the liquid surface: it diminishes the surface energy. It is the reason we have sulphide going into oil or oil contaminated liquid, because the oil has less potential energy when it is so surrounded than if it was in the water. The quartz goes into the water because there it has less potential energy than it would have if it were in the oily layer. I have thus tried to lay a sound physical basis, facts which I believe are accepted by all students of physics, as the basis for the Beach-Taggart explanation of the flotation phenomena in the agitation cell.

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Q. 21. What does experiment 5, sprinkling ore on water, show?

A. It shows an increase of viscosity of the surface layer, including the mineral particle. The portion of the surface which contained the chip was not at all disturbed by the motion of the needle, was not sensibly disturbed by the motion of the needle when there was no powder on the surface. When the powder was scattered over, the whole surface moved almost as if it were a solid body.

Q. 22. What do you mean by viscosity?

A. Well, in popular language, viscosity is internal friction. If I move a book along the surface of the table there is a certain resistance to the motion of the book with respect to the table. In the case of a fluid, when we move one particle of a fluid with respect to its neighboring particle there is similarly a resistance to this motion which is called internal friction and which is a measureable thing and is called viscosity.

Q. 23. Can you illustrate this idea of viscosity in some other way?

A. Suppose we start with a beaker of water and we pour into it some finely divided particles. As we increase the number of these particles which are, we will say, merely mechanically inclosed in the liquid, it takes on a consistency which is more like that of a syrup, it pours more slowly. If we increase the number of these particles more and more we finally get it to a paste, the substance becomes so sticky or so viscous that it may be

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moulded in the fingers. A good example of this is putting whiting in oil, which makes putty. Putty is an example of a substance which is very stiff or viscous. It flows under the force exerted by the fingers, but it flows with difficulty and very slowly.

Q. 24. What is your idea or explanation of this increase of viscosity?

A. Suppose we were to take two surfaces of glass—I can do that best by illustration. Let the line A represent the surface of a glass plate. Let B represent the surface of another parallel plate, and suppose that the region between these is filled with water. Now we are going to move these plates parallel to each other. The water clings to glass. The particles of the water which are right next to the glass are practically adherent to it. The same is true on this side. Now, when these plates slide, one up and one down, the particles which adhere to the glass move with the plates. The other particles that are nearby are entrained a certain amount but the particles which are in the middle space, provided that is not extremely small, will be just about as free to move as if they were in a large pond of water. Now, suppose we diminish the distance <sup>again</sup> between these surfaces. I will represent the plates by position A<sub>1</sub> and position B<sub>1</sub>. Now, you see the particles which attached first to A and also to B are in very close juxtaposition. As we slide the plate A<sup>1</sup> up and B<sup>1</sup> down, the particles stick to A, move with the plate, and those sticking to B move with that plate, but the particles which are in the

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very small distance in between there more or less adhere or rub against these partially fixed particles on the plates so that it is obvious, it seems to me, that the motion of the plates with respect to each other are somewhat retarded by the resistance of these particles that rub against each other. There is a true friction between the parts of a liquid, such as water. All fluids show a certain amount of internal friction or viscosity. Now, that is exactly what happens in the case of the paste that I spoke of. If we magnify these particles enough, these a, b, c, ~~w~~, if these represent particles of the powder that we put in the liquid and if the little interstices of these particles are regarded as filled up with water, then it is obvious that the particles as a whole are not very free to move; they are hampered by the adhesion of the particles of the liquid on the faces which are juxtaposed. That, in popular expression, is my idea of why a paste becomes so viscous.

Q. 25. Will you kindly mark that diagram 14 and initial it?

(Witness marks the diagram.)

MR. SHERIDAN: The diagram so marked is offered in evidence on behalf of the defendants.

MR. WILLIAMS: We have no objection.

Said diagram was admitted in evidence and marked DEFENDANT'S EXHIBIT No. 137.

Q. 26. Professor, you saw the test No. 3 that Prof. Taggart made yesterday, with the beaker, the red ink and the water and the oil?

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A. Yes.

Q. 27. What does that show?

A. I would like to have the diagram that he drew for that, if I might.

Q. 28. It is on the blackboard, Professor, and it has not been offered in evidence as yet.

A. This experiment calls attention to the peculiarities of the banding surfaces or interface between the oil and the water. That interface is obvious. If you look down on it at a small angle it looks shiny, has almost a metallic lustre; but it possesses certain other properties which are important. It shows that there is something there which is different from the pure oil and different from the pure water. There is, in other words, a transition layer here in which, as I apprehend it, the particles of oil are intermingled or mixed in varying degrees with the particles of the water. This transition layer we call an adsorption layer. There is more or less concentration of ~~water~~ <sup>oil</sup>.

P. 3059, L. 22, insert "water, and on the water side it contains some particles of" after "of"

— 1 —  
fabric of which the bubble film in the flotation process is made up. Recalling Prof. Taggart's description, when a bubble of air is released it rises by its buoyant effect, it entrains some of the water in the region; it gradually lifts to the surface which bows over as this elevated portion raises still farther. It necks off at the bottom and incloses some of the colored water. We have inside

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there, sir—we have an adsorption layer of air, water passing from the hole into the water. As we pass from the water into the oil we have another adsorption layer which is almost a skin, if I may use that term, or membrane, out of which we can make bubbles. These rise to the top and this skin may remain intact for a short time and show the reddish color when looking down upon it. But, after a little time on account of the considerable weight that is there dragging it down, that bubble film of the oil-water adsorption layer thins out and breaks and this portion which is sort of like a watch glass or crescent, falls down, will return to the ~~lower~~ surface. Sometimes it will rest on that for a number of minutes before it unites with it. And the distinguishing thing about it is that it does not draw itself together into a spherical drop as the ordinary drop of rain would, falling through the air. It has a very viscous film. And this film is capable of making bubbles. We can fill it full of air, we can fill it full of water, or we can fill it full of oil. I do not know at the moment, but I think I can easily show that we may have that viscous film filled with some water in bubbles containing no air above the surface and we may have that film filled with oil and appearing below the surface. In this connection I would like to introduce if I may—

Q. 29. (Interrupting.) Let me ask a question: Can you show by experiments how the presence of solid particles at an oil-water contact results in increasing the viscosity of the interfacial film at the oil-water interface?

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A. I will endeavor to do so. I have here a bottle into which I will pour a layer of water. This is ordinary tap water. In this bottle I will pour a layer of kerosene. There were temporary bubbles filled with water formed there in the kerosene. I will introduce into this bottle an amount of copper—finely divided copper, bronzing powder it is called. I am now agitating this mixture and will allow it to stand for a moment or two and there will be seen pendant a short film, a flattened film which when looked at by reflected light looks as if it were copperplated. When looked at by transmitted light it shows a lacey pattern. This is a bubble film which has inclosed within it a certain number of these copper particles.

MR. WILLIAMS: Just mention that you shook it again.

A. I have again shaken the bottle. I have here a specimen of the same film which is not air formed here in the copper, but which illustrates the great viscosity of that particular film. Now, in an experiment which I have actually carried out here I will call your attention to the extreme viscosity of that film which now hangs in a vertical position and I would like the court, if the court pleases, to examine it by transmitted light and by reflected light.

Q. 30. THE COURT: What is the purpose of this?

A. This is to show how this interfacial film, which is the fabric by which bubbles are made, has its viscosity very greatly increased by the metal particles which have become imbedded into the film.

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Q. 31. MR. SHERIDAN: Which become imbedded in the film or the interface?

A. Imbedded in the film.

Q. 32. THE COURT: This film hanging down is oil and metal particles?

A. Well, it is the adsorption here. It is the same dividing layer which is seen in this experiment, only it now has been over-weighted so that it hangs down and if your honor will look at it by transmitted light, that is, towards the window, you will be able to see the spaces between the particles, that the film is not completely filled; it shows tracery, lace-work. The film is evidently very viscous, it does not tend to contract as ordinary films do.

MR. WILLIAMS: We would like a specimen of the bronzing powder.

Q. 33. What is that, a powdered copper?

A. I don't know how it is prepared; it is called pulverized copper, which is used by painters for bronzing.

Q. 34. MR. SHERIDAN: Professor, I would like to ask you what you mean by a film? Is the film you are speaking about a film composed by oil in which there are minute particles imbedded, or water in which there are minute particles imbedded, or is it that material, that layer that you call the adsorption concentrate layer between the oil and water face?

A. It is the transition layer, what I call the adsorption layer or adsorption film consisting of particles of water molecules, particles of air molecules, particles of

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oil, and in this case it has imbedded in it some particles of metallic copper. If they were blown up into spherical form it would be exactly like the froth which appears in the concentration cells.

Q. 35. And the presence of the particles that formed that copper powder does what, in that film?

A. These particles make the film viscous in the same way in Prof. Taggart's experiment, the ore which was sprinkled over the surface of the beaker made it viscous, tended to move more like a solid body than like a liquid body. Have I made myself clear?

Q. 36. Yes. Now, returning to the mineral agitated froth. What is the function of the oil in mineral separation?

A. I apprehend that the oil serves two functions. It makes this adsorption layer from which bubbles may be constructed and by its selective adhesion to the sulphide particles or, conversely the selective adhesion of the sulphide particles to this adsorption layer, the particles are separated away from the quartz and brought up to the surface.

Q. 37. Now, Professor, before you depart from this subject I would like to have you give a complete explanation of your test, which we call test No. 12, that you just performed with the glass bottle and copper powder so it will appear on the record.

A. With a diagram?

Q. 38. No, not a diagram. I wish to have you give a complete explanation of it so it will appear in the rec-

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ord. Tell about what you did, materials used, bottles used, and so forth.

A. I selected a glass-stoppered bottle about four inches high, about two inches in diameter. I poured into it a layer of tap water about an inch and a half in thickness, from a wash bottle. I then poured some commercial kerosene from another bottle upon the surface of the water, forming a layer about 1 inch thick. I then introduced into the bottle by the aid of a spatula a small amount of copper powder, known to the painters as bronzing powder, using an amount which would cover about a square centimeter of the surface of the end of the spatula. I then agitated this mixture with the glass stopper in the mouth of the bottle for a few seconds and allowed the material to settle down into its apparent levels. After an interval of a few seconds I again agitated it still further and then noticed—

Q. 39. (Interrupting.) For how long; just state how long you agitated it the second time.

A. Less than ten seconds I think. I do not understand that the time of agitating has anything special to do with it. I then noticed when the fluids had come to rest in the bottle, that there was hanging a web-like structure from the interface of the oil and the water into the layer of water. This is the bubble film matter or the water-oil adsorption layer hitherto discussed. In this particular case it was seen to contain a great number of copper particles. When looked at by reflected light the whole surface appeared as if it were copper

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plated. When it was looked at by transmitted light it had the appearance of a cobweb which has been exposed in a dusty place for a long time. The light can be seen through this filmy structure and one can, undoubtedly, if his eyesight is sufficiently good, pick out the individual particles of the material. The weight of this material stabilizes the film so that it has already remained in existence I should think for about ten minutes, hanging as a cobweb from the upper surface and resting on the bottom of the bottle. A slight agitation of the bottle shows that this is a very viscous film.

MR. SHERIDAN: If you would like to examine the witness on this test before it disappears you are at liberty to do so as far as I am concerned.

MR. WILLIAMS: No, I don't wish to now.

BY MR. WILLIAMS:

X-Q. 40. Professor, I would like one further explanation. Is that film or curtain-like structure filled with kerosene or air?

A. Well, I will answer to the best of my knowledge after looking at it since it was formed. It is my opinion that it consist of intermingled particles of kerosene and water, forming the so-called adsorption layer. It also contains imbedded within it some mineral particles—particles of the copper powder, and I am not able to discover, looking at it with the glass, that it does contain any perceptible number of air particles. I do not exclude the possibility of there being some minute particles there, but there certainly are not enough to float it

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to any degree, and I have not examined it under a powerful microscope.

X-Q. 41. The amount of agitation to which you subjected it was a comparatively gentle agitation, was it not?

A. There was no intention—it was simply to shake the things together. I have not performed this experiment very many times, and I cannot say that a long shaking or a short shaking or a horizontal shaking or a vertical shaking have anything to do with it. The idea is simply to intermingle the substances.

X-Q. 42. Now, that oil there does not contain any visible air, does it, as the result of the shaking?

A. I would like to say that the water bottle which I used contained air; the water was not free from air; I presume very likely there may be some small adhesions of air.

X-Q. 43. It is a characteristic of Butte water that it contains air for some time, isn't it?

A. It is a characteristic of water under pressure at any time that it contains air. I am unable to say that I can see any particles of air with the power of the microscope which I have in my hand.

X-Q. 44. Then that other one that you produced that was done some time ago, there is not any air in that oil there at all, is there?

A. Not in so far as I know.

X-Q. 45. The metal is practically all down at the interface between the oil and the water, is it not, in both cases?

A. No.

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X-Q. 46. First we will take the one that was introduced first?

A. I did not intend to introduce this as an exhibit.

MR. SHERIDAN: Well, refer to it anyway.

X-Q. 47. MR. WILLIAMS: It is instructive to examine it anyway.

A. No, it is all at the interface.

X-Q. 48. Well, a part of it at least?

A. Well, there is some at the upper surface, I cannot say how much there is there. If you remove the cork you will see that there is some there at the surface.

X-Q. 49. There is some of the metal floating at the top of the kerosene layer, and apparently a larger amount—or at any rate a considerable amount of metal floating at the interface, and practically no metal in between the top face of the oil and the interface of the oil and water, that is right?

A. There seem to be no copper particles in the mass of the oil that is away from the surface. There are particles of copper—in this specimen the copper is in the oil.

Q. 50. That is the last test which you made; it has not all settled out probably?

A. It has not settled out; but the copper particles appear at the interfaces; the interface of the oil and the glass, the interface of the water and the oil and the interface of the oil and the air.

Q. 51. I presume you have observed that metal par-

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ticles tend to settle to the bottom of an oil layer when that oil layer floats on water?

A. Some of them do.

Q. 52. That is the extent of your observation, is it?

A. Some of them do and some of them may not.

Q. 53. But in your experiment, the one that was done before the court opened, there has been substantially a settlement of the metal particles to the bottom of the oil layer, except for those particles that are floating on top of the oil layer?

A. I think so.

Q. 54. MR. SHERIDAN: Then, just carrying Mr. Williams' question further, the metal tends to go to the interfaces between the two different liquids or a liquid and a solid?

A. The statement of the result I would put this way, that the metal goes into that medium where its potential energy is least.

Now the conditions are somewhat variable. The potential energy of some of the particles may be least at the air-oil surface, in the case of film flotation. In this I judge that the copper particles have less potential energy at this adsorption layer than they have in the liquid kerosene. Some of them, also, have found positions of equilibrium, creeping up the side of the glass jar. Some of them are entangled up at the top on the cork.

Q. 55. Going back to the agitation froth process, is there any difference in the function of the oil when the

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percentage is less than one per cent or when it is over one per cent?

A. No; in my opinion no.

Q. 56. Is there any point at which the function of the oil in the mixture undergoes a change, short of the simple bulk oil flotation?

A. None whatever.

Q. 57. Will you kindly state, if you know, or state what your opinion is, if there be any difference between an air froth and an oil froth?

A. I am not sure what you mean by an air froth and an oil froth, but I will try to answer the question. If by an air froth is meant one which is formed with a small quantity of oil, more than a fraction of one per cent—more than one per cent—I say there is no difference between those two froths. Have I apprehended your question?

Q. 58. I think you have answered it all right. As I understand, the only difference there would be between froths formed with a fraction under one-half of one per cent, and within reasonable limits up to 25 per cent, would be the amount of oil in the froth?

A. A difference in degree, but absolutely no difference in kind.

Q. 59. In what respect does an agitation froth made with a so-called insoluble oil differ from an oil froth made with say a soluble contaminant, such as creosote?

A. It is a difference in degree, and not a difference in kind. The soluble contaminants may be more effective in producing a foam, and the heavier or selecting

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oils may be those oils which have a greater adhesive power of picking out the sulphide.

Q. 60. Did you hear Professor Taggart's deposition yesterday?

A. I think I did, most of it; I am not sure that I did all of it.

Q. 61. When he referred to the fact, as I remember it, that whether it was a soluble contaminant or an insoluble contaminant, that the contaminant tends to concentrate at the interface of the air and gas; do you agree or not with that proposition?

A. The soluble contaminant?

Q. 62. Both soluble and insoluble as I understand tends to have the least potential at the interface between the air and the liquid?

A. The soluble contaminant will concentrate at the interface provided that it lowers the surface tension, and the so-called insoluble oils also do disperse and disseminate themselves to a certain degree throughout what we would ordinarily call the solvent, and if they lower the surface tension they will concentrate at the interface.

MR. SHERIDAN: Mr. Williams, you may have the witness.

#### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 63. Professor Beach, you illustrated in diagram No. 11 the force of surface tension at the oil-sulphide, oil-water and sulphide-water surface?

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A. May I see the diagram again please?

X-Q. 64. Can you give me any measurements as to these forces; take first the force  $T_{so}$ ?

A. I don't know of any method by which those interfacial forces can be independently measured; there may be some, but they have not been brought to my attention.

X-Q. 65. And therefore you have not, as a physicist, succeeded in making any definite expression of those forces?

A. I have not attempted to reduce them to numerical value.

X-Q. 66. Is the same true as to diagram 12, wherein, in place of sulphides, you use quartz, and represented again diagrammatically the three varieties of surface?

A. I would say that I am not at present aware of any measurements of interfacial tension between a solid and a liquid. The interfacial tension between two liquids has been measured.

X-Q. 67. Can you give me representations in dynes or otherwise of those forces?

A. I may refer to the authorities for that?

X-Q. 68. Suppose you do it after luncheon?

A. All right.

WHEREUPON an adjournment was taken until 2:00 P. M. Thursday, April 26, 1917.

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X-Q. 69. Now, Professor, can you give me the oil-sulphide tension, surface tension under the conditions shown in your diagram 11?

A. I know of no numerical measure of the tension between a solid and a fluid.

X-Q. 70. Now the oil-water surface tension under the conditions illustrated in your diagram No. 11?

A. I will quote value for oil-water surface tension, 14.

X-Q. 71. Would that be dynes?

A. I assume it is. It is not expressly stated.

X-Q. 72. Now, the sulphide-water surface tension under the conditions in your diagram 11.

A. As I said a moment ago I know of no measure of the interfacial tension between a solid and a fluid.

X-Q. 73. Then we come to diagram 12 and the first item was oil-quartz. That comes under your general statement that there is no measurement?

A. I am not acquainted with any measurement of that.

X-Q. 74. Now the oil-water, under the conditions of your diagram 12, oil on quartz?

A. The tension of the water-oil interface is not affected by the presence of this insoluble solid.

X-Q. 75. So we take 14 dynes, that is what you gave before?

A. That was the value that I quoted from this book.

X-Q. 76. And the quartz-water comes under your—

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A. That is a solid interface and I do not know.

X-Q. 77. Now this oil-water surface tension, is it variable with different oils?

A. Undoubtedly.

X-Q. 78. And can you give me any other date than you have given?

A. For oil-water?

X-Q. 79. For oil-water.

A. I will quote from Freundlich Kapillarchemie.

X-Q. 80. MR. GARRISON: What does that title mean when translated?

A. Capillary chemistry. It is capillary chemistry or the chemical phenomena connected with capillarity. It is a branch of physical chemistry. Page 128, table 30, title page bearing date of 1909.

X-Q. 81. MR. WILLIAMS: Published by who?

A. Akademische Verlagsgesellschaft, m. b. H. Page 128, Table 30, various substances mentioned here, benzol—I would like to say that these involve chemical natures of compounds and not being a chemist I am not absolutely sure as to the description.

MR. SHERIDAN: Do you want to have Dr. Sadler or Prof. Bancroft interpret it for you?

MR. WILLIAMS: I will not object.

A. Water and petroleum hydro-carbon; water and benzol; water and turpentine; water and isobutol alcohol; water and iso alynl alcohol; water and ethyl ether; water and chloroform, methyl alcohol and carbon bisulphide.

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THE WITNESS (Continuing): Or water petroleum hydro-carbon 48. That is undoubtedly dyne per c. c. Water-benzol 32.6; water-turpentine oil 12.4; water isobutol alcohol, 1.76; water-isol alynl alcohol 4.42; water-ethyl ether 9.69; water-chloroform 27.7. That is all of that list.

X-Q. 82. Now, can you give me the surface tension of an air-water surface?

X-Q. 83. Now, can you give me the surface tension of the air water surface?

A. Do you desire me to read from this book?

X-Q. 84. Are you reading from the same book you did before? If so, mention it.

A. I am reading from the book, but I must read it in German. I won't be responsible for the translation.

X-Q. 85. Well, let Dr. Bancroft read and translate it?

A. Well, I can read it and translate it, but I don't want to be responsible for the translation; I might make a mistake. "The values measured by different methods, pure water at 18°, by different methods"—then there are twelve or twenty different observers. Will it be sufficient if I give the range of values from the highest to the lowest?

X-Q. 86. Yes.

A. The lowest there which I find in the table is 71.9—well, there is one 71.7, measured by method called air bubbles. The observer is Sieg and this

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measurement was made, or rather published in 1887. The highest value which I see in the table is 76.8; there are two values; one by Timberg, which was published in the *Journal de Physique* in 1887. The value was measured or determined by the adhesions to a ring made of platinum.

X-Q. 87. And these are all at 18° C.?

A. I so understand it to be stated here.

X-Q. 88. Now, the oil-air surface tension; can you give me any figures on that?

A. To tell the truth I don't know how many of these oils—but I will read some.

X-Q. 89. I suggest that you lend us the book and we will look it over and put in evidence what are necessary so as to save the trouble of putting in the whole list?

A. The book does not belong to me, and I do not feel that I have authority to let it go out of my hands.

THE COURT: Do you want this to go in as your own evidence or as a part of your cross examination.

MR. WILLIAMS: As a part of the cross examination of this witness.

THE COURT: Suppose you let Dr. Bancroft read it. I suppose you want to use it as part of the cross examination.

MR. BANCROFT: I will be happy to read it for him or to copy out the table for him.

MR. WILLIAMS: Then kindly read the table, and we will get it in the record.

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MR. BANCROFT: This is a table of surface tension of organic compounds. First, Hexane; temperature 20°; surface tension 17.4. Kerosene: temperature 50°; surface tension 30. Benzol, temperature 20°; surface tension 28.8. Toluol, temperature 20°; surface tension 28.2. Methylalcohol, temperature 20°; surface tension 23. Ethylalcohol, temperature 20°; surface tension 22. Normal propyl-alcohol, temperature 20°; surface tension 28.6. Isobutyl-alcohol, temperature 20°; surface tension 22.5. Isoamyl-alcohol, temperature 20°; surface tension 23.5. Ethyl-ether, temperature 20°; surface tension 16.5. Glycol, temperature 20°; surface tension 46.1. Glycerine, temperature about 18°; surface tension 65. Acetone, temperature 20°; surface tension 23. Formic acid, temperature 20°; surface tension 37.1. Acetic acid, temperature 20°; surface tension 23.5. Propionic acid, temperature 20°; surface tension 26.2. Normal butyric acid, temperature 20°; surface tension 26.3. Analine, temperature 20°; surface tension 43.8. Pyridine, temperature 20°; surface tension 38. Nitrobenzine, temperature 20°; surface tension 41.8. Chloroform, temperature 20°; surface tension 26. Carbon tetrachloride, temperature 20°; surface tension 25.7. Carbon bisulphite, temperature 20°; surface tension 33.5.

X-Q. 90. MR. WILLIAMS: Those degrees are all Centigrade-

A. All Centigrade degrees.

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EXAMINATION OF MR. BEACH RESUMED.

X-Q. 91. You collaborated, did you not, on the paper entitled "An Explanation of the Flotation Process by Arthur F. Taggart and Frederick E. Beach," portions of which I read to Professor Taggart during his testimony?

A. No, sir, not in that paper.

X-Q. 92. Was it written entirely by Professor Taggart?

A. We did not write that paper.

MR. SHERIDAN: I don't think Mr. Williams should ask that question, so I object to the form of the question. How should Professor Beach know anything about it, if Professor Taggart wrote it entirely.

THE COURT: The form of the question is all right, but it calls for hearsay.

MR. WILLIAMS: He might have seen him write it.

THE WITNESS: If the court please, I would like to state that we did not publish in that journal, and I never to my knowledge read that matter which he presented to the court. It is not our paper at all.

A. If the court please, I would like to state that we did not publish in that journal—I never to my knowledge read that matter that he presented to the court. It is not our paper at all.

X-Q. 93. That is to say, this publication which appears in the Metallurgical and Chemical Engineering. Have you read it?

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A. The Journal that you have quoted did us the honor to reprint the paper. It was not by any authorization of my own. I hadn't the opportunity to correct the proof; I don't remember that I ever read the text that you quoted in the court yesterday.

X-Q. 94. I show you a document entitled "Transactions of the American Institute of Mining Engineers" and a paper having the same heading. Will you accept that as authentic?

A. That is our paper, yes, sir.

MR. WILLIAMS: I will have that identified paper marked for identification.

(The paper entitled "Transactions of the American Institute of Mining Engineers" marked Plaintiff's exhibit 138 for identification.)

X-Q. 95. MR. WILLIAMS: I read from the authentic publication: "The importance of flotation lies in the fact that it is primarily a 'slimes process' by means of which the particles of valuable mineral, too fine for efficient gravity concentration, are saved with a high percentage of recovery. Recoveries in the mills treating low grade copper-sulphide ores have been advanced twenty per cent by the installation of the process and similar increased savings can be accomplished by the same means in mills treating sulphide ores of zinc and lead." You accept that statement as authentic from yourself and Professor Taggart?

A. I have not qualified to testify in regard to mill operations.

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X-Q. 96. That is to say you are a physicist and not a metallurgist and you want to draw the line; is that the idea?

A. I do not feel that I can offer testimony upon that technical subject which would have any weight. I am not qualified as a mill expert or a metallurgist.

X-Q. 97. Were you present when I read these extracts to Professor Taggart?

A. I was.

X-Q. 98. Can we save the time by my asking you whether you accept those parts that I read to him?

A. I did not have the copy of the paper present and I do not know that it was an authentic copy.

X-Q. 99. I read from the authentic copy as follows:  
"The conclusion ——

THE WITNESS: Excuse me; would you indicate the page upon which that appears?

MR. WILLIAMS: Page 1376.

THE WITNESS: And what portion?

MR. WILLIAMS: Commencing about the middle, under the pictures. "The conclusions forced by observing the above phenomena are:

"(1) That water has a smaller tendency to displace air on the surface of sulphide minerals than on the surface of gangue minerals.

"(2) That the tendency of oil to displace air is greater at the surface of sulphide minerals than at the surface of gangue minerals.

"(3) That oil tends to displace water on the surface

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of sulphide and that water tends to displace oil at the surface of gangue mineral.

"(4) That water displaces air more readily on an oiled solid surface than on a clean surface of the same solid.

"(5) That these tendencies toward displacement are due to the interfacial tensions or pressure existing between the various substances, and that the resulting action of this interfacial force is a manifestation of the tendency toward reduction of the total potential energy of the system. Whenever an increase in the solid-fluid interface will decrease the potential energy, such a change will occur." Do you accept that as accurate and as representing your views today?

A. No, sir.

X-Q. 100. Is it accurate—is it an accurate statement of what was published in this authentic paper of yours?

A. Well, I desire to say—I do not understand that I have testified to the contents of this paper. This paper is not a part of my testimony in this court. It was not made under oath. It was done in collaboration with my colleague and was done honestly at the time and represented our views honestly at the time, but I desire to say that I am not prepared to introduce it as my testimony and my language in this court.

THE COURT: Well, the object is, you are here as an expert in reference to special matters in this case and they have a right to ask you about other statements that you have made, not that you have sworn to them,

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necessarily, and to see if your views have changed, also.

THE WITNESS: I would desire to state, the physical facts involved there are not stated in the language which I should use. When two men work together in collaboration they do not always look at the facts from exactly the same angle and they frequently have a difference of opinion as to how particular phenomena should be interpreted and they usually—often there are some compromises between the different points of view. This statement here represents, I think, an average of the views of the two authors of this paper. I should be very glad to state my own views in regard to the phenomena which are involved there, but I would, if the court please, rather not say that these are my words because I do not know that they were used by me.

THE COURT: If they are not, of course you will just state what the facts are, as you remember them. It is not an attempt to try to bind you, Mr. Beach, to any particular view, but that we may have a full understanding of how this was written, and you have stated how it was prepared. You have stated how it was written, and you have a right to explain or modify what you now consider to be the truth of the matter.

X-Q. 101. MR. WILLIAMS: I will say that I haven't the slightest desire to trap you into any statement you will not accept, and my purpose in asking you is to know whether you would accept it. Now, if you will explain your views—if you wish to explain your views otherwise as to these phenomena you will kindly do so.

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A. The paragraph numbered one, I should say, expressing my views in regard to the phenomena<sup>M</sup> which I suppose is the real point or crux of the question, that water will displace air more readily from the surface of the gangue minerals than from surfaces of sulphide minerals.

X-Q. 102. MR. WILLIAMS: Which is the anti-thesis of this statement, is it not?

A. It is not, no.

X-Q. 103. All right, I will withdraw that then. All right, go ahead.

A. I think that my statement amounts to the same as is made here, but I would prefer to change the language if I were to offer my testimony in regard to this fact. In regard to the next number?

X-Q. 104. Go right ahead.

A. Oil will displace air more readily at the surface of sulphide minerals than at the surface of gangue minerals.

No. 3, oil displaces water more readily on the surface of sulphide than on the surface of gangue minerals. Water displaces oil more readily at the surface of gangue minerals than at the surface of sulphide minerals.

(4) Water spreads more readily on an oiled solid surface than upon a surface uncontaminated with oil.

(5) These displacements can be expressed in terms of the interfacial tensions or energies and the resulting action of these interfacial forces will diminish the po-

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tential energy of the system. If a change in the area of the solid-fluid interface will decrease the potential energy, such change will automatically occur when the system is freed from constraint. I think, Mr. Williams, that states in my own language the substance of these paragraphs and I desire to say that I do not believe that the sense or meaning of them has in any point been essentially changed.

X-Q. 105. Following what I read and what is expressed in your own language, the paper says: "These conclusions suggested the following confirmatory experiment," and then there is a description and an illustration of an experiment wherein an aluminum ring was cleaned and floated on the surface of pure water, and then the ring was oiled slightly, and it was found that the water came over the surface and that it was impossible to float the ring. You accept that experiment as an accurate experiment, do you not?

A. I do. I would like to enlarge upon that statement a little.

X-Q. 106. Go ahead.

A. I hold in my hand the aluminum ring in question. This ring was floated on clean water. (Drawing diagram.) I have not all the figures in my note book; I think the statement of the dimensions of the ring and the density as given in the paper are correct. This ring was cleaned by washing it with a cake of sapolio, or bon ami; it was washed with soap, thoroughly rinsed, and taken up in clean filter paper so that it did not

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come in contact with the fingers. A small wire carrier with three projecting prongs was used to hold it and drop it down upon the surface of the water. The ring then floated under the influence of the forces of surface tension, which were applied at lines of contact, running around this outer portion of the ring, and the inner portion of the ring.

Q. 107. MR. SHERIDAN: Do I understand that those are two rings, or is it a cross section?

A. This is a cross section of this particular ring, the dimensions being given in the paper.

X-Q. 108. The ring lies horizontal upon the surface of the water?

A. The ring lies horizontal upon the surface of the water. I then attached to this ring some fine copper wires, three of them, I think, making a little basket or pan in which I could put shot, endeavoring to find out how much load in addition to its own weight this ring would support under the influence of these forces of surface tension "T".

X-Q. 109. MR. WILLIAMS: You might mark "basket" at the bottom.

A. I have marked it "basket and shot". I did not expect that this would be called for at this time, therefore I have not provided myself with the data. I will quote from memory, which is to the best of my knowledge and belief. The total added weight which it was possible to put on there was something like 1.7 gms.; I am sure it was over 1 gm., but I am not quite sure

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whether it was one and six-tenths or one and seven-tenths—a variation of one-tenth. The ring was then removed from the water, thoroughly dried, and taken in the fingers; a bottle containing oleic acid was shaken up and the cork was removed, and I rubbed my fingers on the cork so that they were slightly oiled. I then passed the ring through my fingers and rubbed on a little of oleic acid, not enough so I could see it, but so the surface, I believe was coated with a thin film of oleic acid. I then replaced, or attempted to replace this ring as carefully as possible upon the surface of the water, but I found, with whatever care I exercised, it was impossible to float the ring alone. I then tried it with two different oils; the bottles which I used were labeled "crude oil" and "creosote". They had been furnished by Profesor Taggart from a number of specimens, and I know nothing about the history of the oil. I presume he could state it if there was any question. I then found that with the crude oil the ring acted as though it was going to float, but did not; it just wavered at the surface and then sank. There was evidently a difference between the oleic acid and the crude oil in the matter of flotation. With the oleic acid it went down much more promptly. I then tried another oil which was called creosote on the label on the bottle. I found when I had oiled this way I indicated, simply by rubbing it with slightly moistened fingers, that the ring floated—I am still quoting from memory—for a space of seven minutes while it was under observation. I left

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it in my room when I went to lunch, and when I returned I found it was at the bottom of the jar. Whether the janitor had been in the room and it had been disturbed, I do not know. I do know this, that it at least floated for seven minutes. There was a difference in those effects. Now, this I regard as a confirmation of the statements that I have made, in this way: I took this piece of aluminum, which I cleaned off very carefully, rubbing the surface with an abrasive soap, and then some plain soap, like ivory soap, and washed the ring carefully in water and dried it with filter paper and was careful not to touch it at all, and then from a medicine dropper I put upon that surface a drop of water, and I determined what I called this morning the angle of repose.

(Drawing another diagram.)

I found that the angle, as I stated this morning, was approximately  $85^\circ$ ; it varied a little—a degree or a degree and a half either side of that. I then took this surface of aluminum and touched it with the moistened cork of the bottle, and rubbed my finger over it, and put a drop of water on there as before. When I used oleic acid I found the drop had that shape, and that its angle of repose was about  $39\frac{1}{2}^\circ$ . I tried the other oils. The crude oil—this little wavy line represents contaminated surface. With the crude oil I found  $65^\circ$  and with the creosote I found  $69^\circ$ . These measurements were made after the experiment had been completed.

Now, I would like to refer to my first diagram.

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MR. SHERIDAN: You better mark that diagram No. 15, so you can identify it.

THE WITNESS: Referring to my diagram No. 15, the angle between the tangent to the liquid surface and the tangent to the cylindrical surface of the clean water and clean aluminum was a relatively large angle; that angle in the other cases had been diminished; in the case of the oleic acid the angle was between  $39^{\circ}$  and  $40^{\circ}$ . The forces of surface tension in the liquid surface being very nearly horizontal, it had a small vertical component. As this angle was small, there was very little spreading effect.

X-Q. 110. Mark the angle that you say was small?

A. It is this angle here.

A. The angle was smallest in the case of the use of oleic acid. In that case I was not able to support it at all. When the angle had been increased, in the case of crude oil, to  $65^{\circ}$ , it seemed to be just on the point of being supported, the force had been more nearly the original position of the pure water. When the angle increased a little larger to about  $69^{\circ}$  as I measured it, I found that it was possible to support the weight of the ring alone for at least seven minutes—I don't know how much longer—and when the angle had been increased as shown here to  $85^{\circ}$  the vertical component of the force being very much larger, it was possible to support not only the ring but an added weight of something over one gram.

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X-Q. 111. Now, will you kindly mark the other diagram, Diagram 15, and I will offer it in evidence.

The diagram was admitted in evidence and marked PLAINTIFF'S EXHIBIT 139.

MR. WILLIAMS: I will now offer diagram 16.

Said diagram admitted in evidence and marked PLAINTIFF'S EXHIBIT 140.

MR. SHERIDAN: Professor Taggart made two diagrams on the blackboard that are marked Taggart's diagrams No. 1 and No. 2, which we will offer in evidence as defendant's exhibits 141 and 142.

Said diagrams were admitted in evidence without objection and marked DEFENDANT'S EXHIBITS 141 and 142.

X-Q. 112. MR. WILLIAMS: Relative to the statement on page 1385 of the authentic paper in regard to the pneumatic froth process, "sulphide and gangue minerals mixed with water and oil, with or without acid, are run into a tank with a porous bottom through which air is forced. The air bubbles rise to the surface with a coating of solid particles preponderately sulphide, while the gangue particles sink."

"The principles involved in this method are the same as explained in the agitation froth process. The only difference is in the method of introducing air. The result of this difference is that the bubbles in the pulp

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are much larger than in the agitation froth method; they arrive at the surface less heavily laden in proportion to their area; the bubble films are, therefore, less viscous and the froth less permanent."

First I will ask you if I have correctly read from this paper.

A. I believe so.

X-Q. 113. Now, as to these statements, do you accept them as proper statements today?

A. These represent the result of my own observation.

X-Q. 114. On page 1384 I read, "Case 2, Sulphide. Gangue, Water, Oil and Acid —— The addition of acid has the two-fold effect ~~for~~ further lowering the surface tension and increasing the adhesion ratio." Have I read correctly from the paper in question?

A. You have not read the adhesion ratio.

oil-solid.

X-Q. 115. The adhesion ratio is water-solid. I thought perhaps it would be just as clear to the several courts who will have to consider this matter with the statement of this ratio omitted. Is that correct now?

A. It is a correct reading of the passage.

X-Q. 116. Now, what have you to say as to that statement?

A. These are the views which we held at the time the paper was written, from observations which we had made. Today I am still of the opinion that the effect of acid is to bring the water into more intimate contact

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with the gangue mineral, that is, the adhesion of acidulated water to gangue as indicated by the angle of repose, is apparently a little greater than for pure water in the gangue. I understand you are asking me about the effect of sulphuric acid?

X-Q. 117. Yes.

A. I am trying to answer that question. Today I am of the opinion that the presence of sulphuric acid assists in flocculation or precipitation of the gangue, although I do not offer this as an expert opinion, as I am not a chemist and this belongs rather to the realm of physical chemistry than to physics. In regard to the other statement as to the effect of acid upon the surface tension of the water, I have found various statements of various authorities, some saying that it lowers it and some saying that it raises it. The best information that I am able to obtain at the present moment indicates that the presence of sulphuric acid slightly raises the surface tension of water, but only very slightly up to a 10% solution of the acid in water. Have I answered the question:

THE WITNESS: Mr. Williams, may I supplement that statement with one reference?

X-Q. 119. Certainly.

A. I would like to call your attention to Figure 140,<sup>c</sup> page 74, of Freundlich Kapillar Chemie in which the course of the curve, indicating the effect of sulphuric acid on water, is given. The ordinates being the numerical value of the surface tension and the abscissae, percentage of water and acid.

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X-Q. 120. And what, in general, does this table show?

A. That with pure water the tension is a little over 75 dynes and as the quantity of sulphuric acid is raised say, to about 8% which is the first point on the curve, the rise is practically horizontal, indicates no very sensible apparent change. After that, up to about 50% solution, the surface tension is raised to a value a trifle over 79, and after that the higher the concentration of acid, the surface tension seems to fall.

X-Q. 121. So that the more concentrated acid has the lowest surface tension; is that right?

A. That is as I understand the diagram which he has given here. I have not studied this diagram, it has only recently been called to my attention, but I mentioned that to indicate that the rise with small quantities of acid is almost negligible.

MR. WILLIAMS: I think I would like to offer in evidence a copy of this diagram and I will have the copy made. (Page 74, Figure 14c.)

The diagram was admitted in evidence without objection and marked PLAINTIFF'S EXHIBIT 143.

THE WITNESS: May I supplement my statement with a still further remark? That variation of surface tension indicated in this diagram with a concentrate of sulphuric acid is far smaller than the variation between the different measured values which we have already

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quoted for water carrying from 71.7, lowest value, to 76.8, the highest value. The variation there is over 6% between the different determinations of surface tension of water.

X-Q. 122. Is there a selective action of the air in water as between metal and gangue?

A. I don't think I understand your question. I don't understand how air can be in water.

X-Q. 123. Well, you may have a bubble of air in water. That is, I take it, the easiest way to put air in water.

A. Well, please restate the question, introducing the bubble.

X-Q. 124. Is there a selective action of bubbles of air in water as between metallic sulphide and gangue?

MR. SHERIDAN: I would like to have the counsel state whether he means pure, uncontaminated water, because water varies in various sections of the country.

THE COURT: This gentleman is an expert on this question. In his answer he may qualify it or illustrate it or draw the distinction.

A. The condition which you have stated is a rather complex one and I do not feel that I can answer it unless I were to represent to my eye the conditions that you have in mind as to how the bubble is placed with respect to the material. I don't fully grasp the point of the question. I may say this, that as far as I do understand the question, that air is differently absorbed at different surfaces. If you have a piece of sulphide

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in air, there will be a different adsorption of air possibly on the sulphide from what there will be on the quartz. Now, if that is introduced into water the water may displace one of these adsorbed layers more readily from one surface than from the other. But what condition of thing you contemplate as to the position of the bubble of air with respect to the sulphide I do not quite understand.

X-Q. 125. Assume a particle of sulphide immersed in water resting upon the bottom. Assume a bubble of air presented to the bare surface of this sulphide particle by being pushed down to it. What will happen when you, after making a good contact between the bubble and the metal, permit the bubble to rise?

A. May I answer that by a diagram?

X-Q. 126. Certainly.

A. (The witness draws a diagram.) Have I correctly apprehended the circumstances you have in mind?

X-Q. 127. Yes, your sketch represents the condition, and here is a bubble attached to a bubble holder. The bubble of air is brought down and touched to the clean sulphide.

A. Under these circumstances I am of the opinion that this angle of repose, as I have called it, would be essentially the same as the angle that would be made by a drop against the sulphide surface. That is, the angle between the air-water surface and the sulphide-water surface. This is the angle here between the air-water surface and the sulphide water surface.

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X-Q. 128. Now, what would happen if the bubble holder were lifted upwards?

A. The force of surface tension has a certain component. If the particle of sulphide were greater than the total value of the upward pull of surface tension it would not be lifted from the bottom but the bubble would stretch out and would finally neck off, and we should have a complete spherical bubble attached to the bubble holder and probably a little watch-glass bubble attached to the surface, in case the sulphide was too heavy. If the sulphide particle was not, then I should expect that the bubble would lift to the surface through the water.

X-Q. 129. And if the weight of the sulphide particle as immersed in water was less than the buoyancy of the air bubble, the air bubble would lift the metallic particle; is that correct?

A. I think it might. I wish to correct my former statement about what would happen to this bubble. There is another possibility: If the sulphide were too heavy and the bubble holder were lifted this bubble would stretch out in a cylindrical form. The diameter here would become less and it is just possible that the water would creep in from each side until it was detached. That is another possibility. I have not tried the experiment and I can not swear from observation.

X-Q. 130. Now, the purpose of my inquiry was to bring about some explanation as to the selective action of air bubbles. Now, what would happen if there

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was a substitution of gangue for clean sulphide, clean gangue; other conditions remaining the same?

A. A drop of water put upon clean gangue makes a very small flat shape; it spreads out; the angle of contact is very small, and I apprehend that this angle there would be the same as the angle of the tangent there, and there would be a slighter attachment of the air to the gangue than with the sulphide.

X-Q. 131. In consequence of that you would expect that the bubble, by its buoyancy would exercise very little lifting power upon the gangue particle?

A. I would, provided, of course, always, that these surfaces are not contaminated with oil. This is a clean sulphide, no oil present, and clean gangue, no oil present. Would you like me to tell what happens when there is oil there?

X-Q. 132. Yes, suppose you tell us what would happen with oil.

A. I will have to draw another diagram—

(Last diagram marked "Beach diagram No. 17).

MR. SHERIDAN: I offer diagram No. 17 in evidence.

Diagram admitted in evidence without objection and marked DEFENDANT'S EXHIBIT No. 144.

THE WITNESS: Let this represent the surface of sulphide, oiled. Suppose that I moisten my finger slightly with oil and rub it over the surface, and I

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put upon that surface a drop of water. The drop of water, instead of standing up in a large heap, will flatten out so as to make a much smaller angle than that shown in the preceding figure. With the bubble holder the attachment of the air to the sulphide surface will now make a small angle. I have a note book full of measurements, made upon that. It is far less than upon clean sulphide. The clean sulphide is somewhere from  $80^{\circ}$  or  $90^{\circ}$  minimum, and when I use oil it sinks down to  $25^{\circ}$  or  $30^{\circ}$ , and we have here a condition such as if—such that if you begin to lift on that, this part here will run over those oil surfaces; its interfacial surface having been diminished, and the particle will not be raised. I would like to state that I tried out that theory thoroughly, and found that it was insufficient. The moment that I saw a flotation machine in operation I rejected the idea that the particles of sulphide were lifted by the minute bubbles attached to the particles.

X-Q. 133. I will ask you to sketch on that sheet this: suppose that you have sulphide mineral, clean, and water containing soluble frothing agent dissolved in it, what will be the condition?

A. (Drawing) I am representing there a drop of this water with the contaminant, the same as with the pure water.

X-Q. 134. Are you assuming any particular contaminant?

A. I understood you to say a soluble contaminant.

X-Q. 135. A soluble frothing agent. Take acetic acid, for instance?

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A. Do you object to the use of the word "contaminant"?

X-Q. 136. Well, it must be a frothing agent?

A. I don't know what you mean by a frothing agent.

X-Q. 137. Phenol, creosote, acetic acid, amyl acetate, whiskey, valerianic acid—there is a long list of them?

A. I think we could find experimentally what would happen by using a drop of this water with a frothing agent, putting it on the clean sulphide surface and observing that angle. The substances which you have named I have not personally tried. I believe that most of those, as I remember your naming them over, have the effect of reducing the surface tension.

X-Q. 138. That is right.

A. It is my opinion that the effect of these contaminants or soluble frothing agents is to reduce that interfacial tension, and to allow the drop to spread out flat. It can be tried. I have not personally tried it in the case of these substances. I have tried it with sulphuric acid, and in our experiments with sulphuric acid I found the increase here—I am quoting from memory, but to the best of my recollection and belief—I cannot say that there were any exceptions—I will say this, in the majority of cases I found that the angle of repose was less than in the case of pure water, and therefore when we come to the question of the bubble attachment to the bubble holder—I am now giving my opinion—my opinion is that this angle would be smaller than in

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the case of pure water against a sulphide, and that the lifting power of this bubble would be diminished.

(Whereupon a short recess was taken.)

Beach diagram No. 18 admitted in evidence and marked DEFENDANT'S EXHIBIT 145.

X-Q. 139. Now, I would like your explanation, professor, of one other set of conditions. Instead of water, oiled sulphide mineral at the bottom, take the air bubble presented to the sulphide mineral in oil?

A. What are the conditions?

X-Q. 140. Oil; a body of oil, and a bubble lowered in the bubble holder and presented to the sulphide surface as before?

A. I should say that I have not seen or studied this condition, but as a method of investigation it is perfectly general. I should proceed by placing a drop of oil upon the sulphide surface.

X-Q. 141. Which you have done, of course?

A. I have done that, and I know that the angle is small. I have measured a lot of angles, but I have not them with my notes here. The angle of contact between the water-oil surface, and the sulphide surface will be essentially the same here as it was there, and I should expect a very slight attachment of the bubble to the sulphide.

X-Q. 142. You said water; you meant air?

A. Air. Of the air bubbles to the sulphide surface.

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X-Q. 143. And the consequences of that small angle would be what as to the lifting power of the bubble?

A. The air-sulphide interface has a larger amount of surface energy than the oil-sulphide interface. The tendency is for this oil-sulphide area to increase, and the air-sulphide to decrease. Therefore, I should expect, under the disturbances of the original condition, trying to lift it, that the oil would come in from the side, and the bubble would detach itself without causing any sensible lifting power to the sulphide. All these answers have reference to particles of sulphide or quartz that are large compared to the thickness of the ~~absorbed~~ layer or interface; I was not discussing finely ground ore in any of these cases.

(Diagram last referred to marked Beach diagram No. 19).

Diagram admitted in evidence without objection and marked DEFENDANT'S EXHIBIT No. 146.

X-Q. 144. Now, let us assume all the conditions as in diagram No. 19, except that we have finely powdered sulphide on the bottom of your glass or other vessel filled with oil, and an air bubble carried down by the bubble holder and brought into contact with these very fine particles. What then would happen?

A. I would like to draw a diagram of that to make myself perfectly definite. I understand this was to be in oil?

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X-Q. 145. Yes.

A. This drawing represents the presentation of an air filled cavity in a pool of oil to some sulphide particles which are resting on the bottom of the containing glass vessel. This interface between the air and the oil is undoubtedly the seat of a certain amount of adsorption of air. I have no experimental evidence which would indicate that in the absence of water a sulphide particle has any different potential energy in that air-water interface from what it has in oil. I should expect that some of the sulphide particles might be held up by film flotation on the lower part of the bubble, but I have no experimental data which would enable me to predict, although I think it highly probable that if such a bubble were presented, that the surface energy —the surface tension of this layer is a little different, probably a little less than what it is in the bubble, and I should expect to find some of those particles entangled in that layer, especially as their presence there would increase the viscosity, and if they once touched the interface they would not be readily drawn up from it.

P. 3100, L. 25, insert "at the inside of the bubble, and at metal oil surface" after "surface"

... it would depend upon the general adhesive relations of those particular substances, which I have not personally studied. I may say that in general when a particle of a substance gets into an interface, or a number of them get there, they increase the viscosity, and

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it is a little harder to pull them out after they have once been in there; under the influence of the weight of the oil they may get tangled in that viscous interface, and they are not easily removed and shaken off, and I think perhaps the same thing would happen in an air-oil interface in the case you have asked about.

X-Q. 147. You last referred to your test No. 12?

A. Test No. 12, yes.

(Last diagram marked "Beach diagram No. 20").

Diagram admitted in evidence without objection and marked DEFENDANT'S EXHIBIT No. 147.

X-Q. 148. Is there any difference between adhesiveness and absorption, or in what manner are they related?

A. By adhesion I understand the molecular attraction of the molecule of one substance for the molecule of another substance. They stick together, if we discuss it in terms of forces, but in general I prefer to discuss the thing in terms of energy. The result of the molecular attraction between the molecule of sulphide and the molecule of oil is to concentrate a layer of the substance at the interface, and that layer of transition where the concentration takes place, is called the adsorption layer, and the change in concentration is known as adsorption.

X-Q. 149. Can you give me any dimensions as to

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the thickness of the interface where we have a bubble of air immersed in water and containing what you have described as an inner oil layer, I believe?

A. I don't remember using the term, inner oil layer, but to reply to the question as to thickness, I have not any very definite idea; it varies, undoubtedly, with the substance in service.

X-Q. 150. Take, for example, the interface between oil and water of which you have spoken to a considerable extent. Can you give any definite dimensions as to the thickness of that interface?

A. I cannot. It would undoubtedly vary with different oils, and especially with the different solids that happened to be present. In the case of the kerosene and the inky water, that film—I don't call it an interface—but that adsorption film, I should judge, was smaller than in the case where it was loaded up with metallic particles as in that bottle to which you just referred.

X-Q. 151. Now, let us take the simple case of kerosene oil in contact with water and no metallic particles?

A. Yes.

X-Q. 152. Can you give a definite statement as to the thickness of that interface?

A. I suppose that it is more than one molecule thick. Whether it is more than 100 molecules thick, I do not know. I am not aware that any experimental investigation or estimation of that thickness has been made.

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X-Q. 153. Now, let us assume an oil-air surface with no metal present. What would be the thickness of the interface?

A. I don't understand that an interface has any thickness. The adsorbed layer has a thickness. I am not aware that any measurement has been made of the thickness of the adsorbed layer or if it has these things are not known to me. They belong to the realm of physical chemistry and that is not my specialty.

X-Q. 154. Well, can you give us any idea of the thickness represented by what you state as the possible maximum in the case of oil and water, 100 molecules?

A. I can't, expressed in centimeters or inches.

X-Q. 155. It is so impossible for the lay mind to think in molecules that I was trying to find out if you, as a physicist might not help us to get a picture of what was described. Can you do so?

A. Well, the picture in my mind is that we have a layer of molecules in the case of the water-kerosene surface—I suppose that some of the water molecules are dispersed or diffused into the kerosene and some of the kerosene molecules are mixed or diffused into the water. In physics, we do not regard absolute discontinuity, and accordingly things shade off gradually, these things are more or less mixed or intermingled at the interface. As to the thickness of it I have no conception.

X-Q. 156. Now, in case of an adsorption layer of an air bubble immersed in water, can you give a picture

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of the minimum condition wherein that adsorption layer is one such as you have described, containing oil and shading off into the water?

A. I am not quite sure that I apprehend your question. It is the boundary between water and air, the air being within a cavity and the water surrounding that?

X-Q. 157. And there being an oil adsorption layer at the interface of the oil bubble. In other words, the condition that you found when you have oil present in water and air bubbles in the water—and these air bubbles have met some of the oil?

A. I think, Prof. Taggart drew a diagram yesterday and I will refer to his drawing. If I have correctly apprehended the question, referring to diagram 7 of Prof. Taggart, Defendant's Exhibit, 130, referring to the portion of the diagram lettered A, which I understand to represent a face containing air and this to be an oil contaminated surface, and this to be—

X-Q. 158. (Interrupting) and outside of it, water.

A. Water, possibly containing oil or not, as the case may be, but mostly water. I understand that there is a greater concentration of particles of the oil at the interface, that is, where the air begins, because thereby the oil lowers the surface tension or reduces the potential energy of the system and those particles of oil depending upon its degree of solubility, will shade off very rapidly if it is an insoluble oil, so called, and much more gradually if it is a soluble oil. There is also undoubtedly more or less compression or concentration of the air molecules near that surface. If there is a suf-

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ficient amount of oil present then we may have a pure oil at this surface just as in the case where we put a drop of kerosene on a glass of water and the kerosene spreads over almost indefinitely and makes a layer so thin or so minute that it can only be perceived by special tests. Have I apprehended your question, or answered it?

X-Q. 159. Yes. If we assume what are generally called insoluble oils, can you give any explanation of the minimum condition when there would be a substantial concentration at the interface, that quick shading off that you speak of?

A. The minimum condition, I judge, would be a layer of molecules, one molecule thick. That is the least that I can conceive of.

X-Q. 160. And it is conceivable that there may be such a condition?

A. I think so.

X-Q. 161. That is to say, there is no reason why, under the forces that are at work there, you would not be able to spread out on the interwall of the bubble, a layer of oil one molecule thick?

A. I am not sure that I understand the question, but as I understand it, the least amount of oil which would produce a contaminated surface there having the same properties all over, would be a layer one molecule thick. If we had less than one molecule thick they would be more or less bunched together in some places and scattered out in others and the surface would not have the same properties all over.

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X-Q. 162. Now would such a layer, one molecule thick, be of utility in the concentration of ores?

A. I should not suppose it would for the reason that the particles which are being lifted are of a size very large compared with the dimensions of a molecule.

X-Q. 163. What further additional thickness would alter the condition of the problem?

A. I don't quite know what you mean by "the condition of the problem". Do you mean how thick a layer would be operative?

X-Q. 164. I understood that you said something about the surface energies being unaffected by thickness after a certain minimum thickness had been attained, and I would like to get that minimum thickness that you had in mind.

A. That is not my understanding of the statement. My statement was this: That the surface tension of a liquid film, that is, with an upper and a lower surface, a liquid film does not depend on the thickness as long as that thickness exceeds a certain small value: Do you want that thickness?

X-Q. 165. Yes.

A. I can only quote that from memory as I haven't my notes with me. I have represented here (drawing a diagram on paper); a molecule of any substance and here is another molecule of the same substance. Then, the limit of molecular range, I mean the greatest distance which we can separate these molecules and still have this one act upon that, that distance,  $d$ , is, I be-

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lieve, 1/20,000 m.m. Liquid films, soap films have been measured which are considerably thinner than that. By "considerably" half or a quarter. The soap film ceases to show the ordinary colors and becomes dark. That is called the black spot. The thickness of the black spot, I believe, is quite a little less than that. The number I cannot recall at the moment, but if it is thinned out beyond that thickness that film changes its properties in rather an erratic way, and if it is much thinner than that undoubtedly it breaks, but I am unable to quote from memory and I have not sufficient data here to specify that.

X-Q. 166. Have you made any such investigation as to the film obtained in the agitation of froth flotation process?

A. As to the minimum film?

X-Q. 167. Yes.

A. No.

X-Q. 168. You have no measurements?

A. I have no measurements of their thickness. When they are loaded with these metallic particles as in the flotation process they undoubtedly have a thickness which is not of ultra-microscopic character, but a sensible fraction of a millimeter. I mean the whole thing, including the mineral particles which are imbedded in it.

X-Q. 169. There must be, I take it, a sensible difference in the thickness of the adsorption layer around an air bubble when it emerges from a liquid as con-

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trasted with the adsorption layer when it is immersed in the liquid? Is that true?

A. It has a single adsorption layer when it is in the liquid and when it emerges it has a double adsorption layer, one inside and one outside, the thickness of that film being dependent on the metallic load which it carries. And it would—

X-Q. 170. And it would have a definite relation to the thickness of the adsorbed layer of the immersed bubble?

A. I don't think so.

X-Q. 171. Would it be thicker of necessity?

A. Because there are two adsorption layers, I should think it would.

X-Q. 172. Can you give me any definite idea of the thickness of the adsorption layer of contaminated immersed air bubbles in the absence of solid particles in the bubbles?

A. Such information is not within my memory. It is possible that the physical chemists have made such measurements but I can not supply them at the present moment.

X-Q. 173. And as to the thickness of the double adsorption layer or film of the bubble, that has emerged from the water, can you give me anything definite as to that?

A. Why, it may be something in my judgment a quarter as large as that that I have written on the blackboard and it may be anything above that. I do not know that there is any special limit. In the kind of

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phenomena which we had in this experiment No. 7, the thickness of these colored water globules could be anything. The interface there was air, in that particular case, was an air water interface; and the outer surface in that case was an oil-water interface, and the thickness between them as we observed it, might be anything over a millimeter.

X-Q. 174. I would like a definite statement from you as to whether or not the affinity of air for metal is utilized in the froth flotation concentration of ore.

A. In the agitation froth process, or in the pneumatic froth process, ~~is it~~ not. It is not, except in as far as there may be air adsorption in this interface.

X-Q. 175. That is, there may be air adsorbed at the oil-adsorption interface?

A. There may be air adsorbed at any place where air is in contact with another liquid or another solid, but in my judgment, air plays a relatively insignificant part.

X-Q. 176. Now, it is true, it is not, that where you employ oil in the concentration of ores, varied in the procedure of agitation froth flotation or pneumatic froth flotation, that there is an amount of oil so small that you get no practical results at all from it? That is true, isn't it?

A. If I understand the question, no. Will you please repeat it?

(Question read.)

A. Now, I understand if there is any oil present at

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all that it has some influence in forming these contamination layers and it acts in the process.

X-Q. 177. Well, it is a fact, is it not, that you can use too little oil to get any practical result at all?

A. It is all a question of degree, a question of the stability of the film that you get. The actual operation of the mills or the cells, I am not competent to discuss. I would give it as my opinion that the difference between a minute quantity of oil and a large quantity of oil is wholly a question of degree and not a question of difference in kind.

X-Q. 178. Well, now, I am assuming something more minute than the minute quantity of oil. Conceding that, you can get no practical results at all; isn't that so?

A. I don't understand what you mean "assuming something more minute than a minute quantity." Would you put that in figures?

X-Q. 179. I understood when you said "minute quantity of oil" you referred to the minimum quantity of oil that was used and produced useful results. Now, I say if you go down below that you impair your results, do you not?

A. That is a question of technical operation of which I have no adequate knowledge.

X-Q. 180. Now, let us assume that you had one drop of oil to ten tons of water, and suppose you undertook to impregnate that water with little air bubbles by sending the bubbles up through a porous bottom. What would you expect to be the result of that

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one drop of oil in that ten tons of water upon the millions and millions of air bubbles that would be distributed through the mass?

A. I would expect that this oil would adsorb in the air-water surface of some of the bubbles which it first met. It might distribute itself in one bubble or it might distribute itself in a thousand bubbles; and if any one of these bubbles came in contact with a sulphide particle, it might pick up one sulphide particle. Whether that is a commercial operation or not I am not qualified to say.

X-Q. 181. Now, let us start with an ore pulp, and in that ore pulp we have a drop of oil, and ten tons of ore and twenty tons of water, and we agitate that very vigorously, and then we pass it into spitzkastens. We use every possible effort to thoroughly disseminate that oil through the pulp and bring it in contact with metallic particles; what would you expect to happen under those conditions?

A. If I had apparatus sufficiently delicate I should expect to find some air-water surfaces and possibly bubbles which were contaminated with the oil, and possibly a particle or two of sulphide imbedded in it; but it is a needle lost in a haystack.

X-Q. 182. Now, isn't it conceivable that there is some point at which—some point in the oil quantity or degree of oil quantity at which, when added to that pulp, we bring about the concentration in a froth of the maximum number of sulphide particles?

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A. No, not a maximum. If the first condition raised one sulphide particle, and you doubled it, you might get two; if you trebled it you might get three. The thing would appeal to me as a matter of degree. I know of absolutely no dividing line, no critical point of change.

X-Q. 183. But isn't it true that you have got a certain number of sulphide particles in your pulp; you have a certain definite number of sulphide particles in your pulp?

A. Yes.

X-Q. 184. I am assuming all other conditions equal, and I am merely adding oil enough to get, say, ninety per cent of the sulphide particles in that pulp to the surface in the form of froth. Isn't it conceivable that there is a certain quantity of oil that will do that?

A. A certain quantity—depending on what is sufficient to do it?

X-Q. 185. Yes.

A. I suppose it is, but I also suppose that if you attach a little more oil, it will do it just as well or a little better.

X-Q. 186. Now, I am assuming that keeping the conditions equal you have found out just how much oil will do it. Now, do you say that having added a little more oil it will do it better—I can't understand that? After a thing is done it is done. If you will explain, I will try to understand it?

A. Well, by doing it better I mean hold them more securely, make a more stable froth, less likely to escape

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from it, bring it up more readily; it may take longer agitation with a minute quantity of oil than with a larger quantity of oil.

X-Q. 187. Then you think the addition of oil will make for the stability of the froth—the addition of the oil beyond what is necessary to bring them up will make for the stability of the froth, is that correct?

A. As I understand the conditions which are proposed, if we had a film which contained a very sparse layer of metallic particles, the viscosity would be relatively small. If we use more oil, that oil would adsorb upon those particles and more of them would stick to it, and the resulting bubble film would be more stable and more persistent.

X-Q. 188. Then there would be a certain oil proportion by the use of which you would get a certain best condition of stability?

A. I don't know what you mean by best condition.

X-Q. 189. Suppose we start with a certain pulp containing a certain number of metallic particles, and you put in oil and put it through the process, and we find that we have not enough oil to give us what we want; the froth of that certain stability containing a certain number of metallic particles. If we had a little more oil we would approach the condition that we want, wouldn't we?

A. I don't know. I suppose you would bring out more particles and you would get a more stable froth.

X-Q. 190. And there must be some condition when we get the maximum froth?

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A. No, I don't think so.

X-Q. 191. You cannot conceive it?

A. I don't see any condition of maximum.

X-Q. 192. And the more oil you put in the better the results is that right?

A. You will ultimately arrive at bulk oil flotation. You would not have bubbles if you put in oil enough.

X-Q. 193. How much do you know of bulk oil flotation?

A. I will answer again that I am not an expert in technical matters, and I am not competent to answer that question? I don't know.

X-Q. 194. Can you conceive a condition where, having started with a certain pulp and added to it a certain amount of oil, enough to form a good froth containing ninety per cent of your concentrate, with that definite relation, and now you add a little more oil. What do you expect to happen then?

A. I suppose you might get a thicker froth, a froth which looked more oily, which might hold more oil than was absolutely essential, a non-economical use of the oil, some of which might be redundant, but as I stated, I don't feel that my opinion is competent, because I am not an expert in the actual operation. I am only stating my idea of what might happen; in other words, if I apprehend your question, there is an amount of oil, undoubtedly, that is too small to get any discoverable effect. One molecule of oil won't form an absorptive layer, but I don't think that there is any maxi-

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mum there at which the flotation process would cease, before you get to bulk oil flotation.

X-Q. 195. How about a minimum amount of oil?

A. One molecule.

X-Q. 196. One molecule, you mean a layer of one molecule over every bubble?

P. 3115, L. 9, cancel "over every bubble" and insert "of" oil might attach itself to the ore molecule of" after "mole-

come to the surface.

X-Q. 197. That would not be a practical process of concentrating ores?

A. No.

X-Q. 198. Now, let us get up to a practical process; can you give any opinion as to the practical processes of concentrating ores?

A. No, I don't know anything about the practice of concentrating. I am, however, sure that there is no dividing line in the amount of flotation. There may be different amounts of froths—different kinds of froths, some more stable and some less stable, some richer and some poorer, but that is a question for the experts in manipulation and is outside of my field. I have endeavored to explain how the thing occurs. The conditions under which it is to be carried out I don't know.

X-Q. 199. Therefore your statements that there is no critical point is a statement based upon theory and not upon actual knowledge of the practice of the process?

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A. By the word "theory" I do not mean hypothesis. In answering that question when I use the word theory I mean a set of conclusions drawn from certain premises, experimentally established, these conclusions being reasoned out. My opinion is based upon theory as so explained, and my answer as given is in accordance with that.

X-Q. 199½. Suppose I put a case to you of using one-tenth of one per cent of oil to the ore, and obtaining by it a concentrate of high grade with a ninety per cent recovery; that would be a practical process of concentrating ores, wouldn't it?

A. Why, I have heard it so stated; I don't know of the actual operation myself.

X-Q. 200. Now, if you added two-tenths of one per cent, you would be using more oil than would be necessary, wouldn't you?

A. I judge not, from the testimony of the experts.

X-Q. 201. From what testimony?

A. I understood Mr. Wickes to say that in many cases the use of a larger quantity of oil was very beneficial to the commercial results.

X-Q. 202. Then you base it upon what has been said here about these wonderful operations, aiming to use twenty pounds of oil or more to the ton of ore?

A. No, I base it on my understanding of what actually happens in the flotation cell.

X-Q. 203. Well, let us put it this way. Suppose you get a ninety-five per cent recovery with a high grade, and one-tenth of one per cent, or two pounds of oil to

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the ton of ore. Suppose you increase it to twenty pounds to the ton of ore and get the same grade and the same recovery. Is it your theory, that, comparing those two operations, the one using two pounds and the other using twenty pounds, and both getting the same results, that those operations are essentially and in all respects the same?

A. I would not say that the result was the same in every respect, but I would say that the process was the same in kind. It is the process that I am describing, and not the result.

X-Q. 204. Would the concentrate froth be substantially the same?

A. There would be probably differences in the amount of oil detectable in the—on the surface.

X-Q. 205. Most of the oil would go with the concentrate, would it?

A. That depends how much water there was and how much agitation was used and how much mineral was there.

X-Q. 206. Let us take the case of two pounds.

MR. SHERIDAN: I object, because the witness has not qualified as a practical mill operator. I have listened to it a long time. He is not a mill operator at all, and has not testified to mill operations, but simply to the physics of the phenomena.

THE COURT: I think so. He has assumed to testify how the process worked and the functions of these various materials used in it, but nothing—

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MR. WILLIAMS: I respectfully submit that the witness has said that there is no such thing as a critical point, and that he has testified as to the process of concentrating ores. Consequently I am entitled to inquire rather fully as to that matter.

THE COURT: Well, proceed; we will see what the question is.

X-Q. 207. Take the case of two pounds of oil to the ton of ore, where would you find the oil at the conclusion of the operation?

A. I don't know what the operation is that you contemplate.

X-Q. 208. The operation of froth flotation concentration of ores; the agitation froth process or the pneumatic?

A. Again I say that I am not familiar with all the details of this operation. I don't know what becomes of the tailings or what water is spilled or the various cells that carry the circulating load; I am not competent to answer that question; I don't know.

X-Q. 209. Now, the case—take the case of a soluble frothing agent. This soluble frothing agent being dissolved in the ore pulp, is wholly distributed through the pulp, is it not, primarily?

A. That depends what degree of solution you use?

X-Q. 210. Well, it is wholly dissolved; I am talking of it as a dissolved substance in the pulp?

A. Well, soluble substances do not dissolve without limit; there is a limit to solution, and the thing may be saturated and nothing may be dissolved.

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X-Q. 211. I did not say soluble without the further qualification that it was wholly dissolved. Now we have dissolved in the pulp a frothing agent?

A. Do you mean dissolved in the water of the pulp?

X-Q. 212. Dissolved in the water of the pulp if you will, a frothing agent?

A. Yes.

X-Q. 213. Now, that is distributed uniformly through the pulp, is it not?

A. I don't know.

X-Q. 214. Now, let us assume that you put in a soluble frothing agent and put it through the Janney emulsifiers, or the first agitator, then let it flow into the separation box or spitzkasten. That operation has brought about, has it not, the contact of every metal particle with the water containing the dissolved frothing agent?

A. I presume so; I don't know; I never watched it.

X-Q. 215. If a particle of metal is in the water of that pulp containing a dissolved frothing agent distributed and dissolved in it, must it not be in contact with the water containing the dissolved frothing agent?

A. And no other oil or insoluble oil present?

X-Q. 216. Yes.

A. I presume it would be.

X-Q. 217. And has every bubble of air in that pulp not also come in contact with water containing the dissolved frothing agent?

A. I think it would depend somewhat upon the character of the frothing agent.

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X-Q. 218. I am assuming a wholly dissolved frothing agent dissolved through the pulp. Now, I ask you if the air bubbles will not of necessity be in contact?

A. It would make a difference, it seems to me, whether the soluble frothing agent lowers the surface tension or raises the surface tension.

X-Q. 219. I see—I think we have got far enough along to know that the soluble frothing agent, if a soluble frothing agent has to lower the surface tension, haven't we?

A. No.

X-Q. 220. You have not reached that point yet?

A. No.

X-Q. 221. Well, let us take a soluble frothing agent that does lower the surface ~~friction~~, if you wish me to put that as a qualification. Won't every air bubble be in contact, that is immersed in the pulp—be in contact with the water containing this dissolved frothing agent?

A. I am not sure. My opinion is it would depend on the character of the frothing agent, on the amount of the energy of the various interfaces.

X-Q. 222. And when you get <sup>your</sup> concentrate with this dissolved frothing agent, where would you expect to find the dissolved frothing agent? You have floated off your froth and separated it, and you have in your spitzkasten the tailings—where will you find your dissolved frothing agent?

A. I am not even sure that this dissolved frothing agent would collect the mineral particles. You have

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got to specify the character of the frothing agent, whether it has any adhesion to the sulphide. All that has been said in my understanding of the question was that this substance was soluble in water and it produced a froth. Now, I am not sure that the sulphide will tend to migrate into these bubble films any more than the quartz does. We have got to study the character of the particular kind of frothing agent.

X-Q. 223. Well, take acetic acid?

A. I don't know anything about that, but if you will permit me to specify another case, the case of saponin. If saponin is put in water it lowers the surface tension slightly with increased viscosity, and you get a very nice froth, but there is no essential adhesion between the sulphide and the saponin. A frothing agent like saponin does not, as I understand it, produce mineral separation of this kind.

X-Q. 224. I see you have not adopted the terminology of the art—that is, the terminology of the art in the patents at least, that is a mineral frothing agent, and I intended always to describe a mineral frothing agent, a frothing agent that produced a selective mineral froth or selective froth?

A. In the case that you get a froth by such frothing agent, if you examine the froth or the concentrate as it comes up in the froth, I should expect to find a very considerable part of it in that interfacial film.

X-Q. 225. And the concentrate would carry a great part of the dissolved mineral frothing agent?

A. I think so.

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X-Q. 226. And the operation of the process would have robbed the pulp, you might say, of its dissolved frothing agent?

A. To a certain extent.

X-Q. 227. You don't know to what extent?

A. I don't know to what extent. That is entirely outside of my field of investigation.

X-Q. 228. Now, in your direct examination you said that in the agitation froth process of concentrating ores, oil above one per cent and oil under one per cent were the same, but you just made the bare statement. Now, I would like you to put as fully and clearly as you can, your reason for that statement?

A. Well, in the theory in which I have outlined with the physical facts and principles to which we appeal in explanation thereof, I see absolutely no difference in the process of the operation.

X-Q. 229. You recognize, as I understand it then, no difference in the process from a minimum of something less than a pound of oil to the ton of ore, up to the conditions of 200 pounds of oil to the ton of ore?

A. I can see no difference in the physical phenomena nor reason for a failure of the process.

X-Q. 230. With 200 pounds to the tone of ore, would you expect to find that your froth was composed of air bubbles, and metal particles exclusively?

A. I have never seen cell operations with such large amounts of oil and I have no idea what would happen.

X-Q. 231. What is the largest amount you have seen?

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A. I do not know. The amounts were not told me.

X-Q. 232. What is the smallest amount you have seen?

A. You mean in mill operations?

X-Q. 233. In mill operations.

A. The facts were not told me. I simply saw the machines operating.

X-Q. 234. Your practical contact with mill operations has extended over what period?

A. It hasn't any extent: I have seen mills in operation, but I have no acquaintance and no competency to pass upon their operations.

X-Q. 235. Can you conceive of a bulk oil float buoyed by air bubbles in it, like a sponge? Can you conceive of that as being produced by the use of oil, ore and water?

A. I never have seen the bulk oil operation and I am not able to answer that question.

X-Q. 236. Can you give any theory as to the relation of the metal particles in such a bulk oil float, to the air bubbles in that float?

A. All I can state is that the metallic or solid particles would take up that position where their potential energy was least, and that can only be determined by experimental investigation. I think the chances are that if they were to reach the air-oil viscous layer, that they might have some difficulty in leaving it? But, further than that, I have not made any investigation on that point. I can not offer any intelligent opinion.

X-Q. 237. Would the air bubble in that oil layer

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loaded with metallic particles <sup>for</sup> form any useful function other than to make a <sup>hole</sup> hole and diminish its weight?

A. I can not say; I have not seen it.

X-Q. 238. Have you ever seen a float wherein there were oil bubbles and air bubbles, the oil bubbles and air bubbles existing in what looked like a froth but was not in fact an <sup>air</sup> ~~ore~~ froth?

A. I don't understand what you mean by an air bubble, or what by an oil bubble. What is the air bubble made of?

X-Q. 239. The air bubble has a film about it.

A. Film of what?

X-Q. 240. A film which I would say would contain some oil, and have you ever seen in the same float with that, an oil bubble?

A. I don't understand what an oil bubble is; how is that different from the so-called air bubble?

X-Q. 241. Is it conceivable that there could be an oil globule in such a float?

A. A body of oil—a globule of oil might be surrounded with water.—

X-Q. 242. Well, now, that is a float where you have these floating bubbles with their oil adsorbed layer, and metal particles? Have you seen in such a float globules of oil?

A. No.

X-Q. 243. Never?

A. No.

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X-Q. 244. But I take it that your examination of what has been done in mill operations has been of such a recent nature that you really would not express an opinion?

A. I am not competent to pass upon mill operations of any sort or character.

Whereupon an adjournment was taken until Friday, April 27, 1917.

Friday, April 27, 1917, 10:00 A. M.

FREDERICK E. BEACH resumed the stand for further

#### CROSS-EXAMINATION

BY MR. WILLIAMS:

X-Q. 245. Coming now, professor, to the scientific viewpoint, is it not scientifically certain that in the agitation process there may be an amount of oil so small that the process will not succeed?

A. I do not grasp all the question. Will the reporter please repeat it?

(Question read as follows: "Coming now, professor, to the scientific viewpoint, is it not scientifically certain that in the agitation process there may be an amount of oil so small that the process will not succeed?")

A. I don't think that I could specify any quantity of oil so small that it could not be conceded to exert

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some influence in bringing a sulphide particle to the surface in connection with an air bubble. I presume that there are quantities small enough so that the process would not be commercially acceptable.

X-Q. 246. I will repeat the question: "Coming now, professor, to the scientific viewpoint, is it not scientifically certain that in the agitation process there may be an amount of oil so small that the process will not succeed?"

A. I have tried to answer the question as I understand it, that no matter how small the quantity of oil, the smallest quantity that I can conceive will be a molecule. Now, a molecule of oil might attach itself to a molecule of sulphide in this combination, namely an oiled sulphide particle might be entrapped in a bubble form and brought to the surface. Such a thing, scientifically, it seems to me is possible, but I repeat there may be a quantity of oil which is not commercially acceptable or useful. If I failed to apprehend your question will you please put it differently?

X-Q. 247. Is it not scientifically certain that there must be under a given set of conditions other than the oil proportion, an amount of oil so small that a desired proportion of sulphide particles will not be included in the froth?

A. I understand that "desired proportions" have nothing to do with science. Science inquires as to what can or does happen. "Desired proportions" have to do with commercial values. I have tried to answer the question as I understand it. There is no minimum limit

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down to the molecule of the quantity of oil that I can see that would fail to operate. Whether this amount as small as a molecule of sulphide is desired or not hasn't anything to do with science.

X-Q. 248. I will repeat the question, changing the word "desired" to "fixed"?

(Question read as follows: "Is it not scientifically certain that there must be under a given set of conditions other than the oil proportion, an amount of oil so small that a fixed proportion of sulphide particles will not be included in the froth?")

A. If we mean by "fixed" always under a like condition as far as we can produce it, that the same amount shall always be brought up, I should say that there would be, according to the theory of probability, sometimes more or sometimes less; but I cannot say that I see there should be any minimum limit to the quantity of oil fixed in any way than by the least quantity of oil known to science, namely a molecule.

X-Q. 249. Is it not scientifically certain that there must be under a given set of conditions other than the amount of oil, an amount of oil so large that the process won't succeed?

A. What do you mean by the "process?"

X-Q. 250. The agitation froth process.

A. The agitation froth process in mill operations I am not competent to answer.

X-Q. 250½. I asked you about it scientifically. I didn't say anything about mill operations. I asked you for scientific facts.

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A. But you couple with it, as I understand it, a particular process which is a mill process. That process I am not familiar with.

X-Q. 251. You have testified about the agitation froth process from a scientific viewpoint, have you not?

A. Yes, but that process involved the beating of air into a mixture of oil and water and sulphide and gangue. The physical phenomena, physical result, of the process involved in that I have testified to. If by the word "process" you mean such an operation, I can say that I see no limit to the amount of oil which would limit the operation of this process which I have outlined, namely the adsorption of a sulphide particle at a surface, or in other words the migration of a sulphide particle into an interfacial film. The point of the question I understand it is the fixed quantity of oil. The quantity of oil which is involved, for example, in that copper powder experiment has nothing to do with the entanglement of the metallic particle. In that experiment there was an inch of oil. The phenomena would have been absolutely the same if there had been a lake of oil a mile deep. I know of no upper limit to the amount of oil. I have tried to answer the question as I understand it.

X-Q. 252. When you say the process is the same from a molecule of oil upwards is it your theory that, given the presence in water of the minimum quantity necessary to act in the way you have described, and given the necessary agitation and other conditions, it

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acts that way whether an excess of oil over and above that minimum be present or not present?

A. Well, I will try to answer the question as I understood you to put it. It is rather involved. If you have a molecule of oil and a molecule of sulphide, there are certain physical or if you prefer to call it chemical forces of attraction between those. The molecule of sulphide is drawn to the molecule of oil, or vice versa, and there is an adhesion or attachment between them, and they rise together, entangled in the film of an air bubble. I say that the operation of that law or that physical phenomenon is identically the same whether the number of molecules there is one of each, or whether the number of molecules of sulphide and oil are inconceivably great—infinite in number.

MR. WILLIAMS: That is all.

#### REDIRECT EXAMINATION.

BY MR. SCOTT:

R-Q. 253. When an air bubble in the bubble holder is brought in contact with an oiled-sulphide particle, is there any change in the distribution of the oil—by the bubble holder I refer to this little inverted cup.

A. May I illustrate that by a diagram?

R-Q. 254. Yes.

A. In my sketch let V represent a vessel containing some water as shown, with an upper horizontal surface. Suppose we try an experiment of this sort, that we have a stock of wood, a match stick, or suppose we have a

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needle shaped piece of metal or sulphide, that we dip that into the vessel of oil, and when the end of this rod or stick has been oiled that way, present this minute charge of oil to the liquid surface. If this oil was kerosene or creosote or pine oil, at the instant of contact of the oil point with the surface there is usually seen a flash of oil over the surface—seen by reflected light you get the colors of thin films; the experiment is readily visible in that form. Note the condition; we have air on one side of the surface, the interface; we have water below and an oiled stick is brought in contact with that interface. Now, Mr. Scott, I understand that your question conceives a state of circumstances which do not essentially differ in their nature from this. I will try to represent that. Let U represent a glass vessel, and let this represent an oiled sulphide particle or particles which is underneath the surface of the water in this vessel. Suppose that you have a bubble holder such as was discussed in our testimony yesterday, and suppose that you have a bubble there filled with air; we have air on the inside, we have the interface air-water, and we have water. We are now bringing an oiled body in contact with an air-water layer. As far as the physical phenomena are concerned, the conditions are identically the same as they were here; air, water and oiled stick or particle, material of any kind. The physical phenomenon which happens there is a spreading or adsorption of the oil over the interface, and I have no question that there is a layer of adsorbed oil upon the interface of that bubble, just

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as here we find that when the experiment was completed we have an oiled layer or adsorption film in the upper figure. Have I answered the question that you asked?

R-Q. 255. I think so. That will be all.

Diagram marked No. 21 and offered in evidence admitted without objection marked DEFENDANT'S EXHIBIT No. 148.

#### RECROSS-EXAMINATION.

BY MR. WILLIAMS:

RX-Q. 256. What is the thickness of the film which flashes over the water surface when the water surface or bubble surface meets oil as shown in your diagram?

A. I can not quote the figure, but I can quote from memory an authority in which you can find the statement of the measure value. In the popular lectures by Sir William Thompson, he was Sir William Thompson when the lectures were delivered; he has been since known as Lord Kelvin—and in, I think the first volume—I believe there are three volumes; one of the volumes has to do with geology, and one with navigation, and the first one has to do with certain phenomena of physics. I can not quite recall that, but I am pretty sure it is in the first volume of his popular lectures, that in one of those lectures he discusses the minimum thickness of a layer of oil which will respond to the camphor test. In an experiment of this sort, if you take perfectly clear water and drop on it little grains or dust

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of camphor, those particles are seen to move and dance around in a very erratic manner. A minute amount of oil will prevent the camphor from dissolving in the water, and the particles will be then at rest. In that lecture he has carried out a calculation to show ~~that~~ the least thickness might be. The upper limit, the maximum thickness there one can hardly state. If you put on a large drop of oil, a certain amount of it spreads over the surface, and the rest of it gathers together in a little lens-shaped figure, and if you add more oil the lens increases its diameter, until the whole surface would finally become covered to any depth. There is no upper limit, but the smallest thickness that will respond to the camphor test can be found in that lecture. That is my recollection of one instance in the literature of physics that a definite statement is made in regard to the thickness of the oil.

PROFESSOR WILDER D. BANCROFT,  
called as a witness in behalf of the defendant, being first duly sworn, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Professor Bancroft, will you please state your full name?

A. Wilder D. Bancroft.

Q. 2. I will ask you to state the character and nature of your education along scientific subjects?

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A. I have received an A. B. degree in Harvard in 1888. The next year I was assistant in general chemistry and also private assistant to Professor Jackson, doing research work in organic chemistry. The year after, 1889 to 1890, I did research <sup>work</sup> in organic chemistry at the University of Strasberg, working under Professor Fittig. From 1890 to 1892 I studied physical chemistry at the University of Leipzig under Professor Ostwald. I received my Ph. D. degree at Leipzig in 1892. The following winter I spent at the University of Berlin attending lectures on mathematical physics by Professor Helmholtz. In the spring of 1893 I went to Amsterdam and worked for about two months in the private laboratory of Professor Van 't Hoff. The next year, 1893 to 1894, I was an assistant in general chemistry at Harvard and I gave a private course of lectures on physical chemistry on the side. The next year, during Professor Cooke's absence, I gave a course of lectures on physical chemistry. I don't remember whether I was an assistant or an instructor that year. It was one or the other. From 1895 to the present time I have been at Cornell University as assistant professor of physical chemistry and professor of physical chemistry. I don't remember when I was appointed professor of physical chemistry. It was either in 1902 or 1903. I have had no technical experience.

Q. 3. You have referred to Professor Ostwald and Professor Helmholtz and Professor Van 't Hoff. Can you briefly tell us something about these men, what their line of investigation and authority has been?

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A. Ostwald was the man who really developed the modern physical chemistry. He founded the Zeitschrift fuer physikalische Chemie.

THE COURT: What is the name of that?

A. It would be in English the Journal of Physical Chemistry, but I cannot call it that because that is my journal. And he has been the leading figure in the development of physical chemistry. He received the Nobel prize for his work on reactions, velocity and catalysis. I don't know what year he received it. Is that enough about him?

Q. 4. That is all concerning Professor Ostwald?

A. Yes. Helmholtz was an authority on everything. That describes him pretty thoroughly, I think. He began by doing work on the conservation of energy. He and Lord Kelvin were unquestionably the leading two physicists of their time. It is a matter of personal preference which you consider the greater. And he also did an immense amount of work in physiological optics and music and heaven knows what else. Van 't Hoff was the first man to do very much in the way of applying mathematical formulae to reaction velocities. His early work was in organic chemistry, where he developed the theory of the asymmetric carbon atom, which accounted for the optical rotation of carbon compounds. For the greater period of his life he was at Amsterdam. After that he was called to Berlin by the joint action, as I understand it, of the Prussian government and the Prussian Academy of Sciences, a thing which has never happened to any man before in

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the world. When the Nobel prizes were given he was the first man to receive the prize in chemistry.

Q. 5. Have you been connected with any scientific organization?

A. Yes. I am a life member and an ex-president of the American Chemical Society. I was one of the original committee which organized the American Electro-Chemical Society. I am a member of that society and an ex-president. I am a member of the American Physical Society; I am a non-resident member of the American Academy of Arts and Sciences. I am an ex-vice-president of the American Association for the Advancement of Science, section C; I am a member of the Chemist Club of New York and an ex-non-resident vice-president. I founded the Journal of Physical Chemistry in 1896, and I have consequently been the editor of it ever since. I am associate editor of the Journal of the Franklin Institute. I was a member of the executive committee of the Eighth International Congress of Applied Chemistry. I was also chairman of the section on photography and photo-chemistry of the Eighth Congress of Applied Chemistry, and I am now the chairman of the sub-committee on electro-chemistry of the National Research Council in connection with the war.

Q. 6. How long, Professor Bancroft, have you been interested in the subject of flotation concentration?

A. Some time in 1906, presumably in the spring of 1906. I read the articles on the physics of ore flotation by Swinburne and Rudorf and on the concentra-

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tion of metalliferous sulphides by flotation by Huntington. I cannot fix the date any more accurately than that because this number of the transactions of the Faraday Society purports to have been published in February, 1906, but these numbers come out at very irregular intervals and I cannot say now; eleven years afterwards, whether it came out in February or whether it came out in August; but I read it as soon as it came and it presumably came in the spring of 1906. At that time I was not lecturing on anything to which these articles had any special application so that they rather went into abeyance, but when I took up a course of lectures on applied colloid chemistry this came in and in the autumn of 1912 I gave a lecture or a part of a lecture on flotation and I have done the same every year since then. In the beginning it was very little knowledge and mostly guess work, and since then there has been every year a little more knowledge and still a great deal of guess work.

Q. 7. Now, how would you define or describe a froth?

A. A froth is a closely packed mass of air bubbles having a honeycomb structure with liquid films as the cell walls and with each individual cell filled with air or with other gas. That definition excludes things like aerated bread which I think should not be considered as froth.

Q. 8. Is it possible to obtain a bubble with a pure liquid?

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A. It is practically impossible to get a free bubble with pure liquid because the surface tension causes the bubble to break.

Q. 9. And what is necessary in order to practically produce a bubble?

A. You ~~might~~ have in there a third substance which will give a surface film which is more viscous than the mass of the liquid. It may be done then either by concentrating at the surface, which is the usual case, or in special cases by the third substance concentrating in the mass of the liquid, leaving the surface film more dilute.

Q. 10. What substances will concentrate in this way in a surface film?

A. All substances which lower the surface tension of the liquid will concentrate in the surface of the liquid, alcohol and acetic acid, to take two cases, and also any substance which is adsorbed strongly by air.

Q. 11. What effects do alcohol and acetic acid have on the surface tension of water?

A. Both alcohol and acetic acid lower the surface tension of water, and they lower that in all concentration. That is, if you add a little alcohol to water it lowers the surface tension, and as you go on adding more you get the surface tension lower more and more all the way down until you get to pure alcohol. In other words there is no point at which there is either a maximum or a minimum surface tension for any mixture of alcohol and water. The same thing applies for acetic acid and water. That is, we change the—

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that is, with changing concentration the surface tension varies continually from the surface tension of pure water to the surface tension of pure alcohol or pure acetic acid, as the case may be.

Q. 12. And what effect does alcohol and acetic acid have on the viscosity of water?

A. The addition of acetic acid increases the viscosity in all particulars with the changing condition of the acid, from the viscosity of pure water, which is less than that of acetic acid, to the viscosity of acetic acid which is greater than that of pure water. Alcohol, however—and by that I mean ethyl-alcohol—behaves quite differently. The first addition of alcohol increases the viscosity of the liquid and further additions increase the viscosity up to a pint—I do not know the exact figure, but approximately 47% alcohol. From that on, the addition of alcohol decreases the viscosity until you get down to the viscosity of pure alcohol. In other words, a concentration which is somewhere about 47 per cent of alcohol, you have a maximum of viscosity and that goes down on the one side to the viscosity of pure water and down on the other side to the viscosity of pure alcohol, so that it is an entirely different question as regards viscosity from the case of acetic acid; whereas, in regard to the surface tension effect the substances behave exactly alike.

Q. 13. What is the effect of the maximum viscosity in aqueous alcohol?

A. It has a very marked effect on the question of foaming. It is usually stated that aqueous alcohol solu-

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tions foam, but that is not correct, except within a certain limit of concentrations. Since the alcohol reduces the surface tension at all concentrations, it will always form an alcohol rich film in all aqueous alcohol solutions; on the other hand with concentrations with probably from a trace of alcohol up to 47% alcohol, the alcohol rich film will be more viscous than the mass of the liquid, and consequently we shall have conditions of foaming so that if we beat up any aqueous solution from a trace of alcohol up to 47% alcohol or thereabouts—I don't guarantee the absolute accuracy of the figures—the mixture will foam. If, on the other hand, you take a point beyond the maximum viscosity, from 47% down to practically pure alcohol, those mixtures will not foam. Whereas, in the case of acetic acid, where there is no maximum viscosity, all solutions of acetic acid from the very dilute ones up to those which are nearly pure acetic acid, will foam.

Q.14. Can you show this by an experiment?

A. We have an experiment which will show that, and before I do that I would like to say one thing, that in all the experiments that I shall show, I shall of course give the weights which are used in each case, but the absolute values are of no importance whatsoever, because you will get exactly the same phenomenon over quite a range of concentration; for instance, in this experiment with alcohol, we are going to use 95% alcohol, because that is the form in which we buy it; but we would get exactly the same thing if we started with 99.5% alcohol and ran down to 50% alcohol; you

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can vary that proportion say 49% without affecting in any way the character of the result.

In some of the other experiments the range will not be so large, but the absolute values are of no importance whatsoever.

(Test No. 13.)

We have here a square glass jar, into which is poured about a quart of so-called absolute alcohol, which means as a matter of fact approximately 95% alcohol; it contains somewhere in the neighborhood of 95% alcohol and 5% water. We shall then beat that up with—beat that up in this square glass jar and, if luck is with us, you will see that it does not foam much. The time of the beating is quite immaterial, so, in order to save time we will only beat it for thirty seconds, but if anybody wants it beaten longer we will beat it as long as anybody wants it done. We will have to wait a moment until the machine is started upstairs so we will have a current. While we are waiting I will also add that unless otherwise stated the rate of the stirring is always about 1,700 revolutions per minute. Now, I do not guarantee the absolute accuracy of that.

Q. 15. MR. SHERIDAN: Professor, do you know what the diameter of the plates are?

A. I have those here. The rectangular glass jar is approximately four inches by four inches by twelve inches high. We are using a four-bladed propeller, with blades approximately an inch and a half to the centers, and half an inch wide. The diameter of the propeller shaft is approximately half an inch, and the machine is

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driven by a quarter horse power motor. The machine being started, the belt slips off, but you will notice that it is not frothing. That is not important, because the thing had not got up speed. (Machine started.) You notice it is being started up vigorously. I push the switch and there is not anything that even could be called a temporary froth. The bubbles arise, and disappear at once.

(Test No. 14.)

We will now repeat this experiment, starting with 1500 c. of tap water and add about 10 c.c. of the same alcohol, and stir it up about the same length of time.

Q. 16. BY THE COURT: This is to illustrate what?

A. This is to illustrate that in cases where we have a lowering of the surface tension, we may have either foaming or not foaming, depending on whether the surface film formed is more viscous or less viscous than the mass of the solution; in other words what I am trying to prove is that the important thing is to form a more viscous film at the surface. In the case of the alcohol beyond the concentration of 47% alcohol, the surface layer is less viscous than the mass of the liquid, and consequently the liquid does not foam. For concentrations of alcohol up to about 47%, the surface layer is more viscous than the mass of the liquid and consequently the thing does foam. Of course that does not give a permanent foam. We will pour out about 10 c.c. alcohol—as a matter of fact it is ten and a half—and we will add that to 1500 c.c. of tap water, and

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we will stir this as before, about 30 seconds, unless somebody wants it stirred longer. (Starting machine.) You can see the difference in the look of things already. (Stopping machine.) And you see the condition—you see the difference in the behavior—you can see an inch or so of froth there, which of course is not permanent, but quickly dies down, but it is strikingly different from the other.

As far as I know, this experiment with a high concentration of alcohol has never been shown before to any audience. It was devised by my colleague, Prof. Briggs. If there is no further question we might leave this and go on.

Q. 17. Will you state whether salt solutions ever froth, and why?

A. A number of salt solutions will froth; for instance a 5% potassium chloride solution will froth, and Mr. Dosenbach showed in court the other day that a concentrated sodium chloride solution will also froth. This is interesting, because these salts all raise the surface tension of the solution, and therefore concentrate in the mass of the solution, leaving a water rich film or a salt poor film at the surface, and consequently one would normally expect these not to froth. As a matter of fact, however, potassium chloride, to take that instance, lowers the viscosity of the water, and consequently the water rich film is more viscous than the salt rich mass of the liquid and consequently we have a case precisely analogous to this one of the dilute alcohol solution, so that the behaviour of potassium

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chloride solution is accounted for in exactly the same way as we accounted for the behaviour of the alcohol poor solution.

Q. 18. Will you state why these froths that you have been discussing and have shown in the experiment are evanescent and die out?

A. The surface film is more viscous than the mass of the liquid, but the absolute viscosity is very low, and consequently these froths are evanescent, and as I showed in the case of the dilute alcohol solution, there is a very vigorous frothing, but it does not last at all.

Q. 19. What happens in the case of colloidal solution?

A. If we have a colloidal solution, such as soap or saponin, for instance, the surface film is very much more viscous than in the other causes, and consequently the froth is relatively stable. I imagine that everybody has seen soap bubbles. The foaming of beer is due to the colloidal proteins, and anybody who has ever poured beer into a glass knows that you get a foam which can be blown off. In the case of champagne I don't know whether there are any colloidal proteins, but certainly the content is low, and one gets under those conditions a bubbling which gives rise to a very evanescent foam.

Q. 20. What happens when one adds oil to water?

A. If we add enough oil we get a second liquid layer, just as in these cases which we saw yesterday; we have a layer of kerosene as a second liquid layer on top of the water. If the oil is more dense than the

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water we would get the second liquid layer with the oil at the bottom and the water at the top.

Q. 21. What classes of oils do you distinguish?

A. Why, I think it is profitable to distinguish between oils which are practically insoluble in water and oils which are more or less soluble in water. Of course there is no sharp dividing line, but that does not prevent a classification being useful. For instance, it certainly is a good policy in every-day life to distinguish between animals and vegetables, and yet there are organisms which it is very difficult indeed to place under that classification, because the two do merge gradually one into the other, although, for every-day life, most of us can tell the wild flowers from the birds.

Q. 22. How is it that a practically insoluble oil forms a foam?

A. When you add a practically insoluble oil to water it is usually adsorbed by the water and spreads out as a thin film. That thin film gives you largely increased viscosity as was shown the other day, and since this is a surface film which has more viscosity than the mass of the liquid, you will get foaming, as has been shown in the case of the dilute alcohol solutions and the 5% potassium chloride solution.

Q. 23. What would be the effect of adding too much oil?

A. If you add too much oil—that is if you add a small amount of oil it spreads out and gives you a very thin film over the surface of the water; if you add a little more oil—oleic acid, for instance, it draws away

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from the oiled film of the water and gives you a globule or drop of oleic acid standing up there; depending on how you do it; you may get one drop or you may get several drops.

Q. 24. What are non-frothing oils?

A. The very insoluble oils are often called non-frothing oils, but I think it would be better, perhaps, to put it around the other way, that non-frothing oils are always insoluble oils; kerosene, for instance.

Q. 25. Is a practically insoluble oil necessarily a non-frothing oil?

A. No, I think not, because you might have a case where the oil adsorbed air very markedly, in which case it probably would give a good froth in spite of the fact that it was a practically insoluble oil.

Q. 26. What happens with moderately ~~insoluble~~ oils?

A. With moderately soluble oils you get two effects; assuming that you add enough so that you get your second liquid layer—you get first the effect due to the second liquid layer, which is the same in nature as the effect of insoluble oil; you will also get a much greater effect—at least I think it is much greater—due to the dissolved portion of the oil, which will give you much more froth.

Q. 27. What are frothing oils?

A. Frothing oils as usually defined are oils which are either partly soluble in water or which contain a soluble or partly soluble constituent, and which show more or less selective absorption for minerals.

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Q. 28. What is the relation between a frothing oil and a non-frothing oil?

A. They pass continuously one into the other; you might have different oils—hypothetical ones—which are soluble say, 10% in water, 1% in water, 1/10 of 1% in water, 1/100 of 1% in water, and 1/1000 of 1% in water. Certainly the one that was soluble only to the extent of 1/1000 of 1% in water would be classed as an insoluble oil. Equally certainly the one that was soluble 10% in water would be classed as a frothing oil. Where you would draw the line in the other cases is perhaps a matter of personal preference.

Q. 29. Would you name a few instances of what would be classified as frothing oils?

A. Pine oil and eucalyptus oil can be taken as two instances of frothing oils.

Q. 30. What is the relation between a frothing oil and soluble frothing agents?

A. They pass continuously one into the other. If the frothing oil increases sufficiently in solubility, or if you take so little of the frothing oil that it is completely dissolved, it then becomes identical practically with the soluble frothing agents.

Q. 31. What are soluble frothing agents?

A. Soluble frothing agents are substances which give rise to a more viscous film; that is to say, in order to be a frothing agent they have to do that. They may be substances like alcohol and acetic acid

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that are miscible in water in all proportions under the conditions of the experiment. They may be substances like amyl acetate, phenol, aromatic hydroxy compounds, which are only partially miscible in water, or they may be substances like salt, which has a definite solubility in water, and then precipitates in a solid form.

Q. 32. Is saponin a soluble frothing agent?

A. Saponin might be called a soluble frothing agent, except for the fact that it plays havoc with flotation and consequently is usually excluded from it. I noticed that yesterday Mr. Williams elected to call these things mineral frothing agents, meaning thereby that these frothing agents showed a greater or lesser selective absorption for mineral with respect to gangue. There is absolutely no objection to that definition as long as one understands what it means; on the other hand, it is a little better, I think, to say soluble frothing agents, and to note that we are not counting in saponin and things of that type.

Q. 33. Is there any sharp dividing line between non-frothing oils and frothing oils? and soluble frothing agents?

P. 3147, L. 26, cancel "oils" and insert "practically insoluble oils and range" after "with"; cancel "and change"

continuously into a so-called

On the other hand it is a very useful classification for the purposes of discussion.

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Q. 34. How would you classify phenol?

A. Phenol is a good illustration, because it has been classified in two different ways. Dr. Adolf Liebm̄ann said that when you add a small amount of phenol so that it is all dissolved in the water, it is a soluble frothing agent; but if you add an excess of phenol, it is an oil, and therefore, of course, would come under the head of partially soluble oils. That is perfectly legitimate as far as I can see, provided you choose to define things this way, and shows that there is no arbitrary dividing line between a soluble frothing agent and a partially soluble oil; because in this particular case it has been classified, at any rate, as one or the other, depending on the relative amounts of phenol to water.

Q. 35. Are these general relations true of other liquids than water?

A. The whole discussion has really been general; I have used the word "water" because it is more convenient than to talk about liquid A and liquid B; but the relations are true of any liquid where you have formed a more viscous surface film; as a matter of fact the crude vegetable oils, to take a single instance, do froth when shaken. I have never tried that in the square jar machine, but I imagine it would be a gorgeous experiment.

Q. 36. Do they froth more readily than the refined oils?

A. The crude vegetable oils froth distinctly more than the refined oils, because they contain more colloidal

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material, which has been removed to a greater or lesser extent by refining; and as a matter of fact Baskerville points out that this frothing may be used as a qualitative test to show something in regard to the degree of refining.

Q. 37. Is the frothing of the oil important in the flotation process?

A. I think not. As far as I know, it is not; it does not come in anywhere, because under ordinary conditions the amount of oil used is relatively small in comparison to the amount of water.

Q. 38. What kind of bubbles does one get in the case of froths with oils or soluble frothing agents?

A. You get under all conditions a froth which is either an oil layer or an oil rich solution next to the air. In making that statement I am using the word oil in its **broadest sense**, to include soluble frothing agents.

Q. 39. How can a froth be made more stable?

A. Since the instability of the froth is due to the low viscosity of the cell walls, it can be made more stable by adding something or other which will increase the viscosity of the cell walls, or of the films constituting the cell walls.

Q. 40. What would be the effect of adding a viscous non-frothing oil?

A. If one adds a viscous non-frothing oil in suitable amounts, one may easily stabilize the froth. As a matter of fact that can be done with the so-called oil mixture of the Butte & Superior Company.

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That oil consists of 70% fuel oil, which is a viscous oil, 12% kerosene and 18% pine oil, which is a frothing oil. I made one experiment in which 4.5 gms. of this oil was added to 1500 c.c. tap water at about 25°. There was also added one cubic centimeter concentrated sulphuric acid. The resulting mixture was stirred for thirty to ninety seconds, in different experiments, at about 1700 revolutions per minute in the square jar machine that you see there. And a fairly permanent froth was obtained about three-quarters of an inch thick.

Q. 41. Can you stabilize a froth in any other way?

A. A much more amusing way of stabilizing a froth is by adding a solid to it.

Q. 42. What solids will stabilize the froth?

A. Any solid which is adsorbed by the oil layer, by the oil-water interface, or by the oil-rich film, will stabilize a froth more or less completely.

Q. 43. What is the effect of lycopodium powder with

P. 3150, L. 22, insert "first that water and pine oil when stirred give no permanent froth. There is a temporary froth but no permanent one. We showed" after "showed"

and lycopodium powder give no permanent froth and that the lycopodium powder becomes distributed throughout the mass of the water coloring it yellow. If, however, you take 1500 c.c. tap water, 1 c.c. pine oil, and 8.3 gms. lycopodium, put in the square jar machine and stir for about thirty seconds you get a solid, yellow,

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very dry, permanent froth about 1.5 inches thick. The water is slightly cloudy, but not much so. In other words, pretty nearly all the lycopodium powder has gone up into the froth.

Q. 44. Will you show us that experiment?

A. In order that you may see that you get no permanent froth with the lycopodium powder we will put the lycopodium powder into the water and beat that for thirty ~~seconds~~ first. I take it that all of you know that pine oil does not give any permanent froth with water. (Test No. 15.) You see that there is no permanent froth and that the mass of the liquid is cloudy and colored yellow. Now, we will add about 1 c.c. of pine oil and stir again. (Test No. 16.) You see that we get a relatively thick froth and that the mass of the liquid is no longer colored yellow and is only faintly cloudy. Practically all the lycopodium powder has gone up into the froth. I may state also that this experiment has never been shown before to an audience, so far as I know.

Q. 45. What is lycopodium powder?

A. Lycopodium powder is the spore of something or other, of either a moss or a fern, I don't know which. I think it is a fern.

Q. 46. Vegetable matter?

A. Oh, yes, it is vegetable matter, organic matter. It is a seed. I so understand.

Q. 47. What is the effect of white lead?

A. We tried an experiment with white lead, which is

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basic lead carbonate and when water and white lead are stirred together there is no permanent foam. The white lead is distributed all through the mass of the liquid, and makes it a very opaque white. When, however we take 1500 c.c. tap water at about 25°, 48 gms. of white lead and 1 c.c. of pine oil and stir the mixture for half a minute or more we get a stiff froth. It makes no difference whether the pine oil be added to the water before the white lead or afterwards. That is, the order of mixing is immaterial. A great deal of the white lead is not carried up by the oil and the water consequently remains opaque and milky. In the case of the lycopodium powder practically all of the lycopodium powder was carried up by the oil. That was not the case with the white lead experiment.

Q. 48. Can't you perform the white lead experiment?

A. I think so. I hope so. (Experiment No. 17.) You see that there is no permanent froth and the white lead is dispersed apparently uniformly through the mass of the liquid. We will add 1 c.c. approximately of pine oil. (Experiment 18.) That ran about thirty-five seconds. You see that we get a very pretty, thick froth, and that the solution now is not entirely clear. I may say also that so far as I know this is the first time that this experiment has been shown to any audience. I should like also to add one statement in regard to the previous experiment with lycopodium powder. Mr. Williams has just told me that Mr. Higgins has done that experiment before. As Mr. Higgins had not told

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me about that, of course I made the statement that I did not know that it had ever been done before. If I had known that Mr. Higgins had done it I would not have bothered to carry the thing through myself.

Q. 49. Will white lead stabilize the alcohol foam?

A. In experiments that we have made we get no stabilization. When you stir a dilute solution of alcohol and water as was shown in the second experiment you get a frothing which is not permanent. When you add white lead and stir, the frothing is also not permanent, although it looks as though the alcohol froth did not break down quite so rapidly. To make sure of that one would have to follow it carefully with a stop watch which I have not done because I don't care anything about it. The trouble seems to be that the white lead is not adsorbed by the alcohol and consequently does not get into the film. Of course if it doesn't get into the film it can't act as a stabilizer, by definition.

Q. 50. And what is the effect of alcohol and kerosene with white lead?

A. We ran the whole set. Alcohol and white lead and water give no permanent froth because the white lead does not go into the alcohol film. Kerosene, white lead and water give no permanent froth apparently because kerosene is a non-frothing oil. In order to be sure that there was no mistake anywhere we tried a mixture of alcohol, kerosene and water. That gives no permanent froth. In other words we have tried our three combinations. Then we tried a mixture of alco-

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hol, kerosene, water and white lead. We took 1500 c.c. of water and 4 c.c. of kerosene, 10 c.c. of 95% alcohol, and 20 gms. of white lead. These were stirred for a minute or two and a good stiff froth was obtained. The water was still milky because the white lead does not go up completely into the films.

Q. 51. Can you show us that experiment?

A. Yes, sir. (Experiment #19.) We have shown you that alcohol and water give a froth which is not permanent. We do not need to show you that kerosene and water do not, because kerosene, by definition, by general acceptance is a non-frothing oil. We will now show you that a mixture of kerosene, alcohol and water as stated does not give a permanent froth. You get an evanescent froth. It is practically all gone except a few stray bubbles already.

THE WITNESS: We will now add white lead, (Test No. 20) 20 grams of white lead, and we will stir this froth approximately a minute. (Stopping machine.) It is not a very striking experiment; something or other went wrong.

Q. 52. BY MR. WILLIAMS: Tell what you got for the sake of the record.

A. For the sake of the record I will state that there is a very thin line of a froth scum at the top; nothing like what I hoped or expected or thought it should have done. We will start the motor again and see what happens. (Running motor again.) Well, the laugh is on me temporarily. If it is permitted, we will show that

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experiment again when it will work. Something has gone wrong, I don't know what, but it seems to be another instance where the experiment has failed but the principle remains the same.

Q. 53. THE COURT' It is not a question of doing it here, is it?

A. Oh, no; it is simply a case that when I did the experiment before it worked, but in many of these things a very slight change makes a difference. It may be it would have worked better if we had put all the things in at once and had stirred them. In the case of the previous experiment with the pine oil and the white lead, I made actual determinations, that the order of adding made no difference; I don't remember whether I did in this particular case, and that may be the difficulty and it may not.

Q. 54. What are you trying to illustrate?

A. I was merely showing another instance of the fact that one can stabilize by means of a solid, and that this is rather an interesting case, because we had here a so-called non-frothing oil, kerosene, and a so-called frothing agent, alcohol, and that under those conditions we were to duplicate the ordinary practice of a froth stabilized by mineral, using a substance which does not occur in nature as a mineral; merely to show that the general principle was the same, that any solid which comes up under the circumstances into the film will stabilize it. The question of the success or failure of the

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experiment is absolutely immaterial, except that one likes to have them go.

MR. SCOTT:

Q. 55. How does lycopodium powder behave with kerosene and alcohol?

A. Lycopodium powder with kerosene and alcohol gives, or gave, a good stable froth. I have tried 1500 c.c. of tap water, 10 c.c. of alcohol, 2 c.c. of kerosene and about 3 grams of lycopodium powder. After stirring from 30 to 90 seconds a good froth was obtained, which was approximately  $\frac{3}{8}$  of an inch thick, and the water was somewhat cloudy.

Q. 56. Will you show us that experiment, Professor?

A. No, I think not, thank you.

Q. 57. Can you stabilize alcohol froth with lycopodium; were you speaking of lycopodium and alcohol?

A. I am not ready to show that; it is not the one that I want to show. After that we went back and tried to see if we could stabilize alcohol froth with lycopodium powder, and it worked fairly well; that is, we took 1500 c.c. of tap water, 20 c.c. of alcohol and anywhere from 8 to 12 grams of lycopodium; they were stirred for about a minute, and we obtained a pasty froth about half an inch thick. The interesting thing about this experiment—when it works—has been—so far it worked every time, but I don't guarantee anything in future—has been that the whole of the lycopodium powder goes up into the froth, and the water be-

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low is absolutely clear and colorless. It is not a tremendously successful experiment as regards the getting of a permanent froth, because the alcohol evaporates readily from the bubbles, and consequently the froth breaks down in the course of time. I shall be very happy to show you that experiment; that is the one that I think you asked for.

Whereupon an adjournment was had until 2:00 o'clock p. m. Friday, April 27th, 1917.

Friday, April 27th, 1917, 2:00 P. M.

BY MR. SCOTT:

Q. 58. Mr. Bancroft, do you wish to repeat the experiment illustrating the effect of white lead upon alcohol and kerosene in the water? I think it was given #20.

A. (Repeating test #20.) You see we have a thick, stable froth about an inch thick, and the water is still cloudy below it. The trouble with the previous experiment apparently was that we added too little white lead and too much of it stayed down in the water to enable us to stabilize the froth satisfactorily. We ran the thing after the close of court by simply adding more white lead to the thing that had failed and it worked. In this particular one, as a matter of fact, I have changed the proportions as given before so as to play safe, and I will read what this experiment actually was.

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1500 c.c. tap water at 25°; 10 c.c. 95% alcohol; 6 c.c. kerosene; and 48 gms. white lead. It is a little more kerosene, half as much again and more than double as much white lead. While I was a student in Germany I used to go to the opera and the first performance that was given they advertised it in large letters as "First Performance." For the second time they advertised "First Performance Repeated." And, consequently then, this is the first time that this experiment has been shown to an audience with failure and also the first time it has been shown with success.

Q. 59. You stated just before recess, Professor Bancroft, that you could stabilize an alcohol froth with lycopodium. Will you show us that experiment?

A. Yes, I will show that also.

Q. 60. Before you do that I would like to ask you a question about this one you just performed and that is why this mixture stabilizes, having the white lead in it, when kerosene ~~nor~~ alcohol alone will form a stable froth?

A. Well, kerosene is a non-frothing oil, so-called, which means simply that it does not froth readily. It, however, does hold or carry the white lead, the alcohol will froth, but apparently has no carrying power for white lead. By mixing the two, we get the good properties of both. The reason for putting on this experiment was merely to show that we are getting with a mixture, and in technical practice I understand that they do use mixtures a great deal, we are getting a stabiliza-

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tion without using any of the regular minerals. There is one thing that it perhaps might be worth while to say about the kerosene, and that is that kerosene would be classed essentially as a non-frothing oil. That does not mean that it does not froth at all, but that the froth is very unstable and breaks down very readily, but of course if you had a substance there which was adsorbed very much by the kerosene, as you may have with several minerals, then under this condition you could build up a froth. I do not mean to say that in any way you could not build a permanent froth with kerosene if you had a suitable solid, because as a matter fact people have done it.

The other question was the one about the alcohol and the lycopodium?

Q. 61. Experiment showing the stabilization of an alcohol froth with lycopodium.

THE COURT: I suppose we can assume that all of these experiments are to serve some useful purpose?

MR. SCOTT: The experiments are to show the real facts of the frothing, that is to what the stabilization of a froth is due, and I think Professor Bancroft will sum up after a few answers the exact conclusions for which these experiments are the foundation.

A. In the experiment in the stabiliaztion of alcohol froth by lycopodium powder we use 1500 c.c. tap water at about 25°; 10 c.c. 95% alcohol, and about 12½ gms. of lycopodium. And if it works well we ought to get a pasty froth and as I said the solution, the liquid below,

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should be almost absolutely clear. We have 1500 c.c. of water now in there and we will add the lycopodium powder and the alcohol.

(Test No. 21)

THE WITNESS: You can see that that one works as per schedule.

Q. 62. Can you stabilize an acetic acid froth?

A. Yes, acetic acid has been stabilized by mineral at one time by Mr. Dosenbach, and we can stabilize it, using an entirely different substance than has been used before, by putting in lamp black.

Q. 63. Have you an experiment to illustrate that?

A. Yes, we have an experiment to illustrate that.

Q. 64. We will have you perform that one, then.

(Test No. 22)

A. A preliminary run was made with water and lamp black, to be sure that we did not get froth with lamp black alone, so we took 1500 c.c. of tap water and 1 gram of lamp black and stirred them in the machine and we got no froth. The lamp black seems to be distributed uniformly throughout the liquid, except that there are a few patches of thin skin on the surface of the liquid. I imagine that the lamp black is not absolutely pure, as lamp black never is; but so long as one does not get a froth with it, it makes no difference in the principle of the experiment. Then I added acetic acid, 10 c.c. of 99% acetic acid—

(Test No. 23)

99% acetic acid is the form in which it is bought

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from the druggist—and you get a stable, coarse froth, and the acetic acid does not take up all the lamp black, and consequently the body of the liquid remains black.

We have now the water and the lamp black alone. (Running motor.) You see you get a few bubbles which die down at once, and you see the whole mass of the liquid is black. Of course one might have known that it would be, because India ink is made of suitably prepared lamp black, and that dissolves in water. Now we will add 10 c.c. of 99% acetic acid and stir again. (Running motor.) It has been stirred for 60 seconds. We get, under those circumstances, a very small amount of froth; we ought to have got more, but we didn't. We will stir it again. (Running motor.) It looks <sup>again</sup> as though ~~like~~ there probably were not quite enough lamp black in it. Not quite enough lamp black and it does not work well, would seem to be the record for that experiment.

Q. 65. MR. WILLIAMS: Won't you state for the record what you see there.

A. Oh, certainly. The result of the experiment is not a success. There are only a few bubbles which are distinctly not permanent. We are running in rather hard luck.

Q. 66. MR. SCOTT: Would more lamp black make it better?

A. Unquestionably.

Q. 67. Would it be worth while to repeat it?

A. If it were for the sake of the experiment I would

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put in more lamp black and run it; but that is for you to say. If we put in more lamp black it will stabilize it, that is certain.

Q. 68. Suppose you do that and see the effect of adding more. How much did you put in before?

A. Well, another gram ought to do it without any trouble; it looks as though it ought to have done it there.

(Test No. 24, adding more lamp black.)

Now, adding one more gram of lamp black, making a total of two grams, and you get a fairly deep froth made of relatively large, coarse bubbles.

Q. 69. The froth is about how deep would you say, two inches, or three?

A. It is an inch and a half, I should judge, on an estimate. If anybody has a rule we can tell more closely.

MR. WILLIAMS: I have a rule.

A. I will let you measure it; any measurement you take is satisfactory.

MR. WILLIAMS: Something a little less than two inches.

A. That is more than I should have given it myself.

Q. 70. BY MR. WILLIAMS: In speaking of it as a coarse froth, as I look at the bubbles seem to be an inch or so across, many of them.

A. At the top, the upper bubbles are very large, and the lower bubbles are smaller.

Q. 71. MR. SCOTT: What effect does lycopodium have on an acetic acid froth?

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A. Lycopodium does not stabilize it, whereas lycopodium will stabilize two of the others that we have tried. It has no effect or practically no effect on acetic acid, showing that it is a question of selective adsorption, and not of any one substance being necessary to stabilize it.

Q. 72. Can you show that easily?

A. Yes, I can show that.

(Test No. 25)

A. In this experiment we put in 1500 c.c. of tap water at about 25°, 10 c.c. of 95% acetic acid, and about 8 grams of lycopodium powder, and stir for 60 seconds.

A. The foam dies down fairly rapidly, the last part of course going more slowly and leaves just a mere line of lycopodium powder along the top, and nothing in the way of a deep or stable froth.

Q. 73. What effect does white lead have on phenol froth?

A. We tried phenol with white lead. I can give you the actual figures. When we took 1500 c.c. of tap water, 2½ grms. of phenol, 10 grms. of white lead, there was no sign of any stabilization and consequently we did not go on and add more white lead because the bubbles showed absolutely no signs of being coated and it seemed perfectly hopeless.

Q. 74. Can you stabilize the phenol froth without using mineral?

A. Yes, you can do it by adding lamp black. In the experiment as I carried it out at first we took 1500 c.c.

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of tap water at about  $25^{\circ}$  and  $2\frac{1}{2}$  gms. of solid phenol and added 1 gm. of lamp black and stirred and it gave us a very coarse froth. In view of the way in which the lamp black acted the last time I have had another gramme weighed out and so we add at first one and will add another one if necessary. (Experiment #26.) About 60 seconds. We get a small amount, a quarter of an inch perhaps of a coarse black froth. I can get more by adding another gram of lamp black if desired, but it merely takes up time; hardly worth while.

Q. 75. You might, as you have the mixture here, add another gram?

A. (Repeating experiment #26 with the addition of one gram of lamp black.) About sixty seconds. That gives  $1\frac{1}{2}$  to 2 inches of a coarse black foam.

Q. 76. Now, do these experiments show the general theory of frothing to hold good?

A. I think they do. I think they show that the general theory as outlined holds in every detail and enables us to predict what will happen in case of the addition of these stabilizing agents, and that this theory holds for any liquid or any combination of liquid.

Q. 77. What is the state of things in the cell wall of these froths?

A. The cell walls therefore have a layer of oil or oil-rich solution next to the air in all cases, and the cell walls are stabilized by the presence of the adsorbed solid material.

Q. 78. Is there any relation between oil and the total solids in these experiments?

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A. In some of them there was absolutely none because in the experiments where there are no solids in at all of course you cannot speak about the relation of oil or soluble frothing agents to total solids, because it is meaningless. It could be figured out as a million, ten million or one thousand million per cent, just exactly as one would wish to do it.

Q. 79. Is the nature of the froth always the same when no solids are present?

A. The nature of the froth is always the same when no solids are present and consequently of course there cannot be any critical point under these circumstances and so far as I know nobody has ever claimed the existence of a critical point when one had oil and water alone. I use "oil" of course in the broad sense.

Q. 80. What is the effect of a solid?

A. The effect of a solid is to stabilize the froth by making the cell walls more viscous.

Q. 81. And that was the effect of the solids you used in this experiment?

A. Yes, that is the effect of the solids used in this experiment, and as a matter of fact we have used in there lycopodium powder, white lead, lamp black, and of course everybody else has done it with mineral, showing that the nature of the solid is absolutely immaterial except in so far as it determines whether it goes into the film or not. But once you get a solid into the film then it increases the viscosity and makes the thing stable.

Q. 82. Was the effect of these different solids known before?

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A. I had supposed that it was not. I did not know until today that anybody had ever tried lycopodium powder as a stabilizing agent for froth. I know of no record of it in the literature and I did not know of anybody except this case of Mr. Higgins which he did not report to me, naturally—of anybody stabilizing a froth with lycopodium powder or with white lead. The lamp black I imagine has been used.

Q. 83. Do you consider that these experiments prove the correctness of the theory?

A. Why, it is usually accepted as a very satisfactory test of the theory that it enables you to predict results which have not been obtained before. That does not mean that you might not predict results which you cannot perform by means of a theory that is not right, but you can't keep it up long without getting caught.

Q. 84. What is your conclusion in regard to the type of froths?

A. That since the action of the solid is simply to stabilize the film by increasing its viscosity, there is therefore no change in the type of froth due to the addition of solid and consequently we have the same type of frothing process that we have when we have oil and water alone; in other words, a froth with an oil layer or an oil-rich solution next to the air. Always, as I said, using "oil" in the broad sense to include the soluble frothing agents.

Q. 85. Are these froths of the same type regardless of the ratio of oil to stabilizing solid?

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A. They are absolutely.

Q. 86. What ratio of oil to the stabilizing solids have you obtained in these experiments that you have performed?

A. Taking these data that I have one can calculate out a number of results. That is, where a stabilizing solid was used without any gangue, good results were obtained with 1 c.c. of pine oil, specific gravity about .93 and 8.3 gms. of lycopodium powder. That is the experiment that was shown. That is a percentage of oil to solid of about 11%, in round numbers. Then, in the case of the white lead and the pine oil we had 4 c.c. of pine oil and 48 gms. of white lead, a percentage of oil to solid of nearly 8% in round numbers. Then in the experiment with the alcohol, kerosene and white lead, the one that worked, we had 10 c.c. 95% alcohol, 6 c.c. kerosene and 48 gms. white lead, a percentage of kerosene and alcohol to white lead of over 25% in round numbers. In the case of acetic acid and lamp black we had 10 c.c. of 99% acetic acid and 1 gm. of lamp black. That would be a percentage of acetic acid to lamp black of one thousand, in case you take the acetic acid as having the same specific gravity as water. As a matter of fact I think it is slightly denser, which would run the ratio of oil, meaning acetic acid, to total solid up to something over one thousand per cent; but I don't see any advantage in calculating that any more closely.

Q. 87. What conclusion do you draw from these ex-

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periments in regard to the froths made in the presence of mineral?

A. Why, that since the froth is stabilized by the mineral in exactly the same way that it is by the lycopodium or the white lead or the lamp black, that the froths which one gets when working with ore are exactly the same type as the froths that we have made here with white lead and lycopodium and lamp black, and we could have gone on and increased that number indefinitely, if there had been any need of it—consequently I cannot see how there can possibly be any critical point at a ratio of .5% oil to ore or thereabouts; I cannot see that we have any possibility of a so-called critical point in there anywhere.

Q. 88. Can you illustrate that by experiment, the absence of any critical point?

A. Yes; we have three experiments which I will now show, and which are the last three, where we will take different amounts of oil to ore. The froths made with anywhere from one-tenth of one per cent, of oil upwards —. They look exactly like, they behave exactly alike in mill practice and they are theoretically exactly alike. We will show three, one carrying in round numbers .3% of oil, one in round numbers 1%, and one somewhat higher, and I hope that they will all look very much alike; they certainly do when we ran them in advance.

(Test No. 27)

The conditions of the first experiment are, 1500 c.c. tap water at about 30°; one c.c. concentrated sulphuric

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acid; 300 grams Butte & Superior ore, which I am told contains about 17% of mineral—I am taking the ore as it is given—and we add to that one c.c. of oil mixture. I have given the composition of the oil mixture in my testimony this morning, and I am told that the specific gravity of that is about .87, and for our purposes we might call it .9, or we might call it 1., without introducing any error of any account; that is, in this first case, as we have one c.c. of oil mixture to 300 grams of Butte & Superior ore, we have got something under one-third of one per cent of oil to ore, barring mistakes in weighing. We will stir each of these for three minutes at about 1700 revolutions per minute. This is one c.c. of the oil mixture.

Q. 89. MR. WILLIAMS: Did you figure the percentage of oil to ore?

A. It is something less than one-third of 1%. It would be one-third if we called the specific gravity of the oil one; it would be a little less than that if you call it .87. It would be just about .29 of 1% of oil to ore.

(Running motor.)

Just about three minutes.

MR. WILLIAMS: We will want a specimen of this froth for analysis. I suppose we can arrange to divide the froth as we have in cases before?

THE WITNESS: That is for Mr. Scott to decide. As far as I am concerned you are welcome to the whole of it.

MR. SCOTT: You can have samples of the ma-

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terial, and if you wait till we are through you can have samples of the froth.

THE WITNESS: I think we had better have all three of them set up side by side.

Q. 90. MR. SCOTT: I thought you were going to make all three in this one jar.

A. Oh, dear, no; because then people might forget that they looked alike. This is .29% oil to ore.

(Test No. 28)

The next experiment will be exactly like this one, except that we will add 3 c.c. of oil mixture, instead of one cubic centimeter. That will give in round numbers a ratio of oil to ore of .87%, in case you take the specific gravity of the oil mixture as .87. To run it up or down a little will run the percentage up or down also. I have not determined the density of it, myself. This will also be run three minutes, exactly the same as the preceding one, the only difference in the experiment being in the difference of the ratio of oil to ore.

(Running motor.)

About three minutes.

(Test No. 29).

The third experiment of this series, and the last one to be shown today as far as I know, is the same as the other two, except that 5 c.c. of oil mixture are added instead of 1 c.c. in the first case and 3 c.c. in the second. If we take the specific gravity of the oil mixture at .87, that figures out in round numbers 1.45% of oil to ore (running motor). About three minutes. I think it will

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take an expert to see any fundamental difference between those three froths.

MR. WILLIAMS: Now, Mr. Scott, may we have specimens of each of these froths, after court has adjourned?

MR. SCOTT: It will only take a few minutes, your honor, to supply these samples, and I think we may as well do it now.

MR. WILLIAMS: I would just like to call your attention also to the showering of the zinc in this last froth.

MR. SCOTT: You have been stirring it?

MR. WILLIAMS: No. The showering of the globules of zinc, that came down, as shown there at the very beginning. Your honor did not see that side of it. It is a little plainer there than anywhere else.

THE COURT: You mean that it has fallen down?

MR. WILLIAMS: That the zinc has fallen from the froth down and mixed with the gangue.

MR. SCOTT: There is the same thing there in each one of these others (referring to each of the three samples).

THE COURT: No objection to taking these samples now if you desire.

MR. DOSENBACH: I am afraid if I mix them up I can't tell which is which.

MR. SCOTT: I don't remember how they were put up.

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MR. WILLIAMS: That is perfectly clear. This is the last.

THE WITNESS: If your honor please, I should like to correct one statement which apparently was in error. I understood that this Butte & Superior ore had a mineral content of about 17%. I am told now that as a matter of fact this particular ore runs about 12.6 mineral. That makes absolutely—has absolutely no effect on the experiment because we are weighing out 300 gms. of ore and the ratio as given are of oil to ore.

MR. SHERIDAN: 12.6 zinc.

THE WITNESS: All right, we will get it straight somehow. I am now told that it is 12.6% zinc. It has no bearing one way or the other except I would like to have it straight.

Q. 91. MR. SCOTT: Is there any reason why a soluble frothing agent should not in itself produce separation?

A. There is no theoretical reason why a soluble frothing agent might not be used by itself to produce separation; and cases of that sort are known.

Q. 92. In which separation has been produced?

A. In which separation has been produced by the use of the frothing agent alone.

Q. 93. What is the objection to using soluble frothing agents alone?

As a general thing the adsorption of the frothing agent by the mineral is not very marked and conse-

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quently the flotation is not as satisfactory as one would like in most cases.

Q. 94. And how has the difficulty been got around?

A. The difficulty has been got around in a great many cases by adding a non-frothing oil, so-called, which is adsorbed very strongly by the mineral and which consequently has very marked flotation power.

Q. 95. What about carrying oils, so-called?

A. The non-frothing oils which are adsorbed very strongly by the mineral are usually termed "carrying oils" because they hold up the minerals. They do not in themselves make so much froth.

Q. 96. Which will be washed out of the mineral more readily, the carrying oil or the frothing oil.

A. Since the carrying oil is adsorbed more strongly by mineral than is the frothing oil, when you use a mixture, the frothing oil will necessarily be washed out of the mineral if you treat it with water more rapidly than will the carrying oil. If the frothing oil were adsorbed more strongly than the carrying oil there would be no point in adding the carrying oil.

Q. 97. Is this true experimentally?

A. I have no direct, personal knowledge on the subject, but I am told that that is the case. I have been told it personally and I have read it in various places; but I have never made any experiment on the point myself.

Q. 98. What would be the effect of treating a frothing oil with a large quantity of water?

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A. That would depend a little on whether the frothing oil were a pure oil or whether it was an oil having soluble or somewhat soluble contents. If you wash a pure frothing oil with water repeatedly you dissolve a certain portion of it, anything up to one hundred per cent. As an illustration you might cut it to ninety per cent or eighty per cent or seventy per cent or sixty per cent, depending on how long you washed, but the oil that is left will of course be identical in kind with the original oil, although less in quantity, and will consequently have the same frothing power. If, on the other hand, you have an oil which contains soluble or partially soluble contents then if you wash you will wash out these contents and you will be left with the so-called insoluble content of the oil and you will have passed from a frothing oil to one which approximates more or less closely, depending on the degree of washing to a non-frothing oil.

Q. 99. What is the theoretical relation between the amount of oil and the amount of the ore?

A. If you had the ideal state of things where you got one hundred per cent recovery and one hundred per cent of concentrate it is quite evident, if everything else is kept the same, the quality of the froth and the quantity of the froth will depend solely on the ratio of oil to mineral. That is because under these circumstances the gangue is merely an inert substance at the bottom of your vessel.

Q. 100. What would be the effect of gangue?

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A. Of course in so far as any gangue is carried up into the mineral, that is going to change things. In so far as any mineral is carried down by the gangue, that is going to change things, and so far as the gangue carries down some oil, apart from the oil that goes down with the mineral, which may be the case, that will also change things so that the relation may easily be obscured, somewhat.

Q. 101. Is it necessary always to use the same per cent of oil to mineral?

A. No, that is not necessary at all because of the fact you can stabilize the froth with varying amounts of mineral. That is—of course you get froth of a slightly different character but over quite a wide range of oil to mineral, you will get a pretty nearly stable froth and consequently it is not necessary to keep the ratio of oil to the mineral absolutely constant; and I imagine that is one reason why people have overlooked the fundamental importance of the ratio of oil to mineral. It is a very natural thing to do.

Q. 102. Within your information is there anything in mill practice, any evidences in mill practice that the ratio of oil to mineral is an important thing?

A. I have no personal knowledge of the mill practice, but in Mr. Wickes' testimony the other day it appeared that it was the practice to increase the amount of oil somewhat when the tenor of the headings run out. And other people have told me that that is a general practice. It looks a little as though the mill practice were distinctly in advance of the patents in suit.

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Q. 103. Have you made any experiments yourself on that point?

A. Nothing very accurately. I made one rather crude experiment merely to satisfy myself how much variation there was likely to be. To fifteen hundred cubic centimeters of tap water at 50°—there or thereabouts—there were added 300 gms. tailings which I am told contained about one per cent mineral, which would make, in other words, about 3 gms. of mineral in 300 gms. of tailings. There were also added 1 c.c. sulphuric acid and 1 c.c. pine oil. In the second experiment the mixture contained 1500 c.c. tap water, 5 gms. of what I was told was 65% concentrate containing roughly about 3.3 gms. mineral, very nearly the same as in the other case, 10% difference if you take the tailings as being absolutely 65, which I assume is not important. one cubic centimeter sulphuric acid and 1 c.c. of pine oil. Under these conditions you have the same amount of water, the same amount of acid, the same amount of pine oil and approximately, within the limits of the analyses given me, the same amount of mineral; but in one case you have got a great deal more gangue than in the other. And now when these were stirred, it did not come out quite the way I hoped it would—there was distinctly more mineral in the froth, judged by the eye, in the second case where I was using the concentrate than in the first because of the larger amount of gangue, carrying down some mineral, so that it is only an approximate experiment and a crude comparison, but it is

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really surprising to see how nearly alike the two froths were when we consider that the percentage of oil to ore was about .62 in the one case—I think that is probably figured on a specific gravity of .9—it is of no importance anyway—and about 18.6 in the other. That is the ratio of oil to ore was something like thirty times as great in the one case as in the other, but the ratio of oil to mineral was practically the same. And, while the froths were not identical, they were very similar indeed.

Q. 104. You used the word mineral, meaning metalliferous mineral all along?

A. Meaning metalliferous sulphide; I assume that that was the correct technical term. I would be very glad to change it if it is not.

Q. 105. What would be the variations in the dilution of the pulp?

A. If you have a soluble frothing oil present in the oil mixture that you are using, having more water in the pulp will of course give you a more dilute solution, and will consequently affect the frothing power; it would be more or less equivalent to using less of your frothing oil; consequently one would expect to find that in any given case, if you keep everything else constant and increase the amount of water in the pulp, you would have to add more oil.

Q. 106. Have you any information as to mill practice that would serve to confirm that conclusion?

A. That part was brought out in Mr. Wickes' testimony, that when the amount of oil in the pulp was in-

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creased—I prefer not to say diluted, because there seems to be some difference of opinion about that; some people say that the dilution increases when you have more water and some people say that the dilution increases when you have less water—so I prefer to say that in Mr. Wicks' testimony it seemed to appear from his data that more oil was needed when the pulp contained more water. I have been told since then that that is the opinion among many of the mill men. I have no personal knowledge of it, beyond hearsay evidence of this sort.

Q. 107. Under what conditions would these relations occur, strictly?

A. These relations, as I said, would hold strictly for the case of 100% recovery of a 100% concentrate.

Q. 108. But such a state of things is not realized, is it?

A. As far as I know, such a state of things is not realized either in mill practice or in the laboratory.

Q. 109. What are the disturbing conditions?

A. There are a good many things that make trouble there. If the froth is too stiff, of course there will be a tendency of the gangue to become entrapped in it. If the gangue is very finely divided, it will settle more slowly, and consequently the tendency of it to be entrapped will be greater. On the other hand there will also, of course, be a tendency for the mineral to be carried down by the gangue, either because it is entrapped or it may be because when bubbles coated with mineral come in

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contact with gangue during the agitation, some of the mineral will be rubbed off mechanically, and consequently will be in the same state as it would have been if it had never been attached to a bubble. And further, of course, the stiffer the pulp, that is, the less water in the pulp, the greater the danger of the mineral being carried down. Of course the actual effect of those things will vary in each particular case, with the nature of the ore, the nature of the gangue, the nature of the oil used, the temperature, the question of what you add in the way of sulphuric acid or copper sulphate, and with the nature of the stirring; so that it is probably a very complicated problem. But by keeping everything as nearly constant as possible, temperature, sulphuric acid, nature of ore and nature of oil and degree and manner of aeration, so that your only variables—your things that change—are the concentration of the pulp and the amount of oil and therefore the change in quantity—then I think that there would be no difficulty in verifying all these conclusions from mill practice.

Q. 110. Will the use of moderate amounts of oil give better results than the use of a minimum amount?

A. Why, it seems to me that it should, because, if you did not have too stiff a froth, you will get more chances for the gangue to settle, and of course also if you get your oil bubbles overloaded with mineral, again there will be danger, so that I would imagine that you would not get the best results in case one worked down to the minimum possible amounts of oil. As I said, I have no personal knowledge of that, but I suppose—I haven't

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the slightest doubt but that mill practice will confirm that statement.

Q. 111. What will happen if a single particle consists both of mineral and gangue?

A. Of course if you have a single particle that has mineral on one side and gangue on the other, no amount of flotation will separate those two; it will either go up into the froth or down into the gangue, depending on the relative amounts of mineral and gangue in the particle; and the only remedy I see for that is more efficient grinding.

Q. 112. Up to this point you have a theory which covers the whole ground to your satisfaction?

A. It seems to me that the theory which I have stated enables us not only to describe all the facts that are known, but to predict a number of facts which were not known before.

Q. 113. What type of froth is produced by these conditions?

A. Under all of these conditions as far as stated, you get the same type of froth, one with the cell walls having a film of oil or oil rich solution next to the ore, and the cell walls are stabilized by the presence of the mineral, which makes the films more viscous and therefore more stable.

Q. 114. Is there any change in the type of froth at or about one-half of one per cent. of oil to ore?

A. There is absolutely no change in the type of froth at any such point.

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Q. 115. On what does this hypothesis of the critical point rest?

A. Well, that is a bit of an unkind question, but it seems to me that the hypothesis of a critical point rests on unverified and unverifiable statements.

Q. 116. Does the Cattermole phenomenon occur at any definite ratio of oil to mineral or oil to ore?

A. No, the Cattermole phenomenon does not occur at any definite ratio of oil to mineral or oil to ore. The Cattermole phenomenon, which is the granulation of the particles into minute lumps imbedded in oil, will take place at entirely different ratios either of oil to mineral, which is the proper way of putting it, or oil to ore, which is unfortunately the ordinary way of putting it, depending on the degree and manner of agitation; that is, it can be run so that you will get granulation when you have got relatively small amounts of oil, and it can be run with the same oil and the same ore, yet the granulation does not take place at those ratios. In other words, the important factor in there is not the ratio of oil to mineral, or the ratio of oil to air; it is the degree and manner of agitation.

Q. 117. Now, professor, Bancroft, will you summarize for the court your conclusions, with such references as are necessary to the illustrative experiments you have presented.

A. The question to be decided was first as to the type of froth that we have in the case of flotation and, secondly, whether this froth changed in type at any given ratio of oil to ore which, as I have said, is

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a bad way of putting things because it does not represent facts, or of any ratio of oil to mineral. Consequently I began back with the simple question of oil and water, using oil again in the broad sense to denote an insoluble oil, so-called, a soluble frothing oil, so-called, or a soluble frothing agent, so-called. In all these cases we get the formation of a surface film at the interface between water and air which is more viscous than the mass of the liquid and consequently when beaten up with air, such a liquid foams or froths; and it does it under all conditions; and it foams and froths only, so far as we know, when the surface film is more viscous than the mass of the liquid. And to illustrate that we did the experiment with alcohol and water showing why certain concentrations do foam and certain other concentrations do not foam. In the case where they do not foam the surface film is not so viscous as the mass or the bulk of the liquids. Then the question comes up as to the type of froth that you <sup>get</sup> when you have oil and water alone. Since we know that the oils absorb air more strongly than water does, we know that under these circumstances and with all ratios of oil to water with which we are working we get the same type of froth in which you have bubbles of air, since we are working with air. The films constituting the walls of the froth are either an oil layer, if you are using enough oil to give you a separate layer, or an oil-rich solution in contact with air. Now,

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go further into the film and you will get water containing less oil than in the surface film, and that part of it would be less viscous. Consequently we have the same type of froth throughout when water—when we have oil and water alone. And, as I said, so far as I know, that is not disputed as yet by anybody. Then these froths are—at least the froths that I was considering—are all more or less evanescent. That is, they break down very quickly; some of them break down extraordinarily quickly. If we make these films more viscous in any way we shall stabilize these froths and get froths of varying degrees of permanency, depending on the viscosity that we produce under these conditions. Now that can be done by means of a very viscous oil, and I cited the case of the oil mixture of the Butte & Superior Company where they have a relatively large amount, 70% of fuel oil, which I understand is a very viscous oil. And that does give, because I know personally, a more or less permanent froth without any other stabilization. On the other hand, you can stabilize the film by introducing into it a solid which will stay there because the presence of the solid in there increases the viscosity just as increasing the amount of ore in a pulp would increase the viscosity of the pulp. Then of course the next question is what substance will go into that film and will stay there? Any substance, any solid which is adsorbed strongly by the oil layer, by the oil-water interface or by the oil-rich solution,

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will pass into that part of the film—The question of stabilization by means of a solid under these circumstances is absolutely independent of the chemical nature and origin of the solid except insofar as the chemical nature determines whether the substance will go into the film or not. That is, you may have the case where the mineral goes in and the sand does not. If you find a hypothetical oil which may exist, although I do not know of it, which adsorbs sand or gangue very strongly, then you could stabilize your film with sand or gangue. There would be no profit in it, but it could be done. Instead of hunting for that hypothetical oil, which would probably take a good while, it seemed to me it was simpler to take a number of different solids which could be made to stabilize certain froths and to show that under these conditions the chemical nature of the solid had absolutely nothing to do with the problem, and that the whole question was whether you had a solid which did go into the surface of the film. In order to show that I have taken—of course everybody knows it in regard to mineral—I have taken among others lycopodium powder, which is a vegetable product. As I said, it is the spore either of a moss or a fern, I don't know which—but I have taken white lead, which so far as I know does not occur as a mineral anywhere, and certainly the white lead that we used did not occur as a mineral, and I have taken lamp black, which is a different substance. The only rea-

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son for taking those things is that I think that I have read somewhere, although I cannot lay my finger on the reference, that somebody or other said that only those substances floated which were metals or were like metals; that is, in other words graphite, which conducts electricity metallically, and the crystallized sulphides which do look like metals—which have a distinct metallic luster. In fact I think in that same paragraph which I am certain I saw but I cannot find it although I looked for it, there was also a statement that they believed that precipitated zinc sulphide would not float because it was not crystalline and metallic. So, it seemed to be very desirable to try the experiment with substances which did not resemble metals in any respect; and I cannot see any way in which anybody could claim lycopodium powder or white lead as being similar, either in properties or origin to a metal. Personally I would not want to classify lamp black either under either head although of course it is carbon, one form of carbon, and graphite is another form of carbon. If anybody insisted that this was an immaterial point I would be willing to meet him half way on that although I should still think he was wrong. I have shown that under these conditions these things go into the film; further it is not a property of the particular substance in itself since we have selective adsorption. Mineral goes into an oil in preference to gangue. Consequently in the same way when we start with different soluble froth-

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ing agents or oils we may get selective adsorption so that a substance which will stabilize one froth will not stabilize another. The lycopodium powder stabilized the pine oil, which is a soluble frothing oil, so-called and it stabilized the alcohol, which is certainly a soluble frothing agent; on the other hand lycopodium powder had no stabilizing effect whatever on acetic acid. That is, in other words, you are getting a selective adsorption; the lycopodium does adsorb alcohol and does adsorb pine oil to a sufficient extent to enable it to stabilize the froth, while lycopodium does not adsorb acetic acid in sufficient extent to give us a stable froth. In other words, the whole thing is selective but it is not, however, a peculiarity to acetic acid, that you cannot stabilize it. We know that we can stabilize an acetic acid froth by means of mineral and I showed that we could stabilize acetic acid by means of lamp black and I further showed that we could stabilize phenol by means of lamp black; that on the other hand, we could not stabilize phenol by means of white lead. I did not try white lead with acetic acid because the probabilities are that the acetic acid would react with the white lead. Now, I could have gone on, if I had had unlimited time and so had everybody else, and have worked up an indefinite number of other substances that would work exactly the same way; but it seems to me that lycopodium, white lead, lamp black and mineral are sufficiently definite to establish the principle that the

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nature of the solid is of no account, so long as it is adsorbed. Now, since the only function of the solid, from the theoretical point of view, is to stabilize the froth, and since it is the solid which is adsorbed in the surface of the film which stabilizes the froth, there can, therefore, be no change of type in the froth; and since the froth, in the absence of the solid, is all of the same type, that is with an oil layer or an oil-rich solution next to the air, it is still of the same type when you add the solid and there is not any possible way, so far as I can see, that the solid should cause that froth to turn inside out or to do any other laboratory tricks, and consequently we come to the theoretical conclusion that the type of froth does not change with varying the amounts of oil in there and that is confirmed by the experimental fact that when you make a froth under the different conditions as shown in the experiment with the three jars on the edge of the desk, you cannot possibly recognize any difference in type in these three froths, although one of them contained in round numbers 0.29 per cent of oil to ore; one contained .087 of oil to ore in round numbers, and one contained 1.45 per cent of oil to ore, also in round numbers. Further, then, the whole nomenclature seems to me rather footless, if you will permit me to use that word; that is, people talk about "the ratio of oil to ore". Now, except so far as the gangue goes up into the froth or the mineral goes down into the gangue, it is perfectly clear that the important thing in any particular case is the ratio of oil

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to mineral and not the ratio of oil to ore; and that, so far as one can see, is also confirmed to some extent by mill practice where the operator is judging by eye the looks of the froth—perhaps I ought not to say that he is judging by the eye because I do not know that definitely—but anyhow it seems to be the practice that when the amount of mineral in the ore goes up, they add more oil. And of course I admit that there is a certain picturesqueness about expressing things in the ratio of oil to ore. That is if you take about one tenth of one per cent of oil to ore it apparently appeals to one's imagination that that is a very remarkable, striking thing, and a very low amount of oil in reference to the ore, which is true. On the other hand, if you figure that around as it should be figured in the case of the ore containing seventeen per cent mineral your ratio of oil to mineral is approximately six per cent, allowing for errors in multiplication and division, which is not half as impressive. If you go down further to the case of an ore containing four per cent mineral why, this same thing figures out 25% of oil to mineral, which is—well, that is beginning to be interesting again but on the other side. I cannot see any possible scientific justification for referring the amount of oil to the amount of ore because the important factor in there is the ratio of oil to mineral and it does not seem to me that mere picturesqueness is important, under the circumstances. On the other hand, I am quite willing to concede that this is a point on which people can very easily be misled because you can stabilize a

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given froth fairly satisfactorily with varying amounts of mineral and consequently it is possible to work with a given oil and a given ore and vary the ratio of oil to mineral over quite a range without necessarily getting bad results; and I think that that is possibly the reason why people have gone to pieces in this case and have laid stress on the ratio of oil to ore when they really meant the ratio of oil to mineral.

As I said, of course you get that most clearly in the unrealizable case where you have 100% ~~recovery and~~ concentrates, which, as far as I know, never occurs. You will get disturbing forces so that, when the froth is stiff, it will naturally entrap more of the gangue, and consequently give you a lower grade concentrate. When the gangue is very finely divided and consequently settles very slowly, that also will be a factor giving you a higher amount of gangue in the froth; on the other hand, when your gangue settles very rapidly, it is likely to carry down a certain amount of mineral with it. That mineral may be either entrapped mechanically, or it may be that you get an actual mechanical rubbing off of the mineral from the films of some of the bubbles. In fact in some of the photographs that were shown the other day you could see in places where the bubbles had come in contact with the face of the glass, that the mineral was entirely gone from them, and you got a shining film, the mineral being off at the side of the bubble. Now, the only other thing that comes in as far as I know here are some of the questions in connection with the feed. I have already stated that it

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seems to be mill practice to increase the amount of oil when the mineral content of the headings runs up. When the amount of water in the pulp runs up, we have two factors coming in, the factor pointed out by Mr. Taggart, that we have a higher concentration of the mineral particles and consequently a greater possibility that they will not all become entrapped in the bubbles, and you have also the possibility that you dissolve out more of your frothing oil from your oil mixture that you are using, in case you are using an oil mixture, and that consequently you are working with what is analogous to a different oil. The differences, may not be very great, but it would be real difference. So that those are all factors which come in and disturb the situation. Then, of course, you also have the possibility of varying the nature and kind of the agitation, either by using a different machine, by stirring more rapidly, or by feeding in more air, and those things will all have their effect in changing the amount of froth and the quality of the froth; that is, going back simply to the case of oil and water, if you put that in a bottle and shake it by hand, which is a primitive and tiresome method, you can only convert a relatively small amount of oil over into bubbles for the same cross section of the bottle, because we do not shake it violently enough. On the other hand, if you take it with a more efficient stirrer, then under those conditions you can run up the amount of the oil in proportion to the cross section of the vessel and get a great deal more froth, as has been shown by these

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things that we have worked here. It would have been quite impossible for me to have taken one of those glass jars, even if I had a stopper for it, and had shaken the oil and water in that and have produced the amount of froth that we could in the other case. Consequently the kind and nature and amount of the aeration will play a very large factor in determining what ratio of oil to mineral you can use safely, so far as I can see, you can vary the amount of oil to mineral over a very wide range and still get a froth—of course not the same froth, but identical in its properties—by simply changing the absolute amount of air that you pump in in a given time, and the way in which you pump it in. I think that covers pretty nearly all of the points, though not all.

Q. 118. If one has a relatively heavy mineral particle under water and coated with oil, and if an air bubble is brought near it, what will happen?

A. The air bubble will attach itself to the oil and will tend to raise the particle. If the particle is relatively heavy, the oil will neck out—the tensile strength of the oil is not high—and consequently the bubble will not raise the particle, but will pull off a small amount of the oil from the particle, and will go up as an oil bubble. Now, you can go on repeating that, and you will take off a little oil every time, a little more oil, and you will get down to the point where, instead of having a thick film of oil on the bubble with relative little tensile strength, you have a very thin film of oil, which under those conditions is both more viscous than the

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mass of the oil, and also ~~of~~ greater actual tensile strength, and then you will come nearer and nearer to lifting your particle. If that particle is large enough you cannot lift it under any circumstances; if it is of a medium size you will reach a point, by the removal of the oil, where you will be able to lift it. The smaller the particle is, the easier it will be to lift and the less oil it will be necessary to remove from it; so that, with a very small particle you can lift it and should be able to lift it even if it were oiled pretty thoroughly heavily, and with a larger particle you would have to get down to a relatively thin film of oil before you could succeed in lifting the particle.

Q. 119. When an air bubble meets an oil globule without violent agitation, what will happen?

A. Again the air bubble will tend to pick up the oil globule, and the oil, or some of the oil will pass around in the interface between water and air, just exactly as it does when you put oil down on a flat surface of water in a beaker in contact with air, and just exactly as was shown in one of the diagrams this morning by Prof. Beach. Now, the oil, of course, barring the influence of gravity, would tend to concentrate uniformly in a film around the air; under the influence of gravity, of course it could not be quite uniform; in fact it distinctly will not be uniform, and you will get more of the oil down at the lower end of the bubble; and since the thick film of oil—I am using thick without giving any definite limit to the size for a moment—is not stable, and consequently the oil will pull off, and

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you will have your air bubble with a thin film of oil around it, and the rest of your globule of oil will be drifting around wherever fate may take it; it depends on the arrangement of your apparatus.

Q. 120. Would it seem likely to you that these things you have stated might cause one to conclude that the air bubbles do not directly attach themselves to the oil globules, and have slight, if any lifting power?

A. Why, if a man were just simply doing the thing, without knowing very much what he was doing or without having any special theory <sup>either</sup> to guide him or hinder him, as the case might be, I think it would be a perfectly natural mistake for a man to make, and I would expect a man who observed those things and did not analyze them carefully, to draw exactly that conclusion. The conclusion would be wrong, however, in spite of its being a plausible one.

Q. 121. Does it seem probable that one might draw a conclusion that air bubbles do not attach themselves to metallic particles coated with sufficient oil to produce adhesion?

A. If you were working with a sufficiently large particle, that would be the natural conclusion to draw from the experimental evidence if you did not analyze it. It would be an inaccurate conclusion, for the simple reason that it is not so.

Q. 122. What would be the more accurate way of putting it?

A. Why, I should prefer to draw the conclusion

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under those conditions, that the cohesion between oil and oil was less than the adhesion between oil and air, and that consequently when you put the strain on it, the break comes in the oil, and the bubble carries off a small amount of oil with it; which is exactly what it does experimentally.

Q. 123. Can you give any illustration of a similar nature from some other field?

A. Yes. If you take a solution of gelatine or glue in water—and of course glue is simply impure gelatine—and put it in a glass beaker and let it dry, it dries down to an apparently solid mass. If you allow that to dry still further by putting it in a very dry atmosphere, the adhesion of the gelatine to the glass is so strong, that even though you have got a smooth bottom in your beaker on the inside, that gelatine holds on to that so strongly that when you take it off it pulls pieces of glass off of that surface. The experiment does not always succeed, because sometimes it breaks the beaker all to pieces, simply doing it a little more; but when you get the thing going, where you get it finally with a gelatine film that has torn pieces of glass right out of that surface—you can conceive what force it would take to break little pieces of glass off the smooth surface of the window pane with your fingers—it gives one a realization of the force that may be acting in the case of a surface film where you have two different substances. Of course I do not mean to say that your oil film could, under any circumstances pull pieces out of the mineral particle, even

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though the mineral particle were large; but it does bring out this other point.

We have another instance of much the same thing in a glue joint. If you glue two pieces of wood together in a careless way with a pretty thick glue joint in there, then under those circumstances the strength of one part of the glue to the other does not amount to very much, and the thing will break at the joint every time. If you do that thing in an honest, workmanlike manner, with your glue warm, so that it goes into the wood a little, and do it with as little glue as you can, and press practically all of the glue that there is there out, so that you have the merest thin film of glue between the faces of the two pieces of wood, then you will get a joint, which, when it breaks, will usually break somewhere else. Of course if the thing which you were to glue were two trees, butt to butt, I imagine under those conditions probably if they broke that they would break at the glue joint; but under ordinary conditions that arise in cabinet making for instance, a first class glue joint is stronger than the wood. That is not a question of mill practice; that is actually experience.

Q. 124. If air bubbles are produced in pure water, would you expect them to be large or small?

A. I am assuming that you are having your bubble produced from a tube or some other orifice. The size of the bubble produced under those conditions depends on two things; first, the size of the opening, secondly the surface tension of the liquid in which the

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bubble is produced. If you stick to the same sized orifice, you would get a larger bubble the higher the surface tension of the liquid, and as you are dealing in this particular case with water, you would get relatively large bubbles. Of course that does not mean that if you worked with an infinitely small orifice the bubbles will be as large as a balloon, but they will be much larger than they would be if you worked in another liquid which had a lower surface tension, because those two things, the size of the orifice and the surface tension of the liquid are the two forces which determine the size to which the bubble may grow before it tears loose.

Q. 125. If anything were added to the water which reduced its surface tension, would you expect the bubbles to become larger or smaller?

A. They would of course become smaller, because that is one of the very nice and satisfactory methods of determining the relative surface tensions; that is, you take a glass tube of a given size, and you let air bubbles out of that into different liquids, and you will get the largest bubbles in the liquid, as I have just said, with the highest surface tension, and in the liquid with a lower surface tension you get smaller bubbles, or with the same liquid if you have added something to it which lowers the surface tension, you will get smaller bubbles, and that is the—is one of the recognized ways—one of the easy ways of getting a qualitative test of the relative surface tensions. You may also go at it around the other way, of course, by letting the liquid

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run out of the orifice. For instance, let the liquid run out of a burette either into the air or into another liquid, depending on what you want to study. If your liquid has a high surface tension your drop will grow to a relatively large size before it breaks off from the burette. If it has a low surface tension you will get a much smaller drop, or if you take a liquid and do anything to it, add soap or saponin or salt or something of that sort, your drop will be larger or smaller depending on whether the surface tension is increased or decreased, and in that way the thing can be used as a quantitative method of determining the surface tension, that is, you weigh the number of drops, or a given amount of the liquid, and work back from that to the surface tension. Under ordinary conditions that is not very accurate, because the theory calls for a drop which breaks off cleanly and leaves nothing behind, but if you run a burette or anything of that kind, we know that under ordinary conditions you get a drop coming off, not clean; there is a small drop left behind. It has been shown by Morgan of Columbia that if you use—I don't know the exact conditions, but if you use a tube with a bevelled end, instead of a tube that simply comes down square, under those conditions a clean drop is removed, and he has used that as a quantitative method of determining relative surface tensions of different liquids and different solutions. So that, of course, you would get a smaller bubble in case you added anything to the water which lowered the surface tension, and conversely you would get larger bubbles if you added

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anything to the water which increased the surface tension. That is first principles.

Q. 126. Do oleic acid, phenol, cresol and amylaceate lower the surface tension of water?

A. They do.

Q. 127. If bubbles generated from small orifices—in solutions of these substances, might we get an effect which could be described as smoke?

A. I see no reason why you should not. If we have a very fine orifice the bubbles in themselves will be small; and if we add to the water anything which reduces the surface tension, your bubbles will be smaller still, and consequently it is merely a question of how small your orifices are what your definition of smoke is, whether you would call the thing a smoke or not, but I can not see any reason why you should not get a cloudiness in there which could perfectly legitimately be called smoke. I never tried the experiment, but it sounds perfectly reasonable.

Q. 128. What can you say about the liquid film in contact with the air of the bubble?

A. Well, I have been trying to say that a great many times all day, that in all these cases you have either an oil layer or an oil-rich layer next the air, and that—if you do not want to use the word "oil"—if you have phenol in solution, ~~then~~<sup>at</sup> the film in immediate contact with the air will be higher in phenol than the mass of the liquid. The same thing will be true of

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cresol and with amylnactate and with anything else of the same type that may come up.

Q. 129. Do you agree with the proposition that mineral frothing agents are generally ~~not~~ oils or oily in character, ~~so it is a~~ and which ~~use the~~ mere incident that oils are also mineral frothing agents—the word mineral being used to mean metallic sulphides?

A. I should think that was a very misleading statement. In a sense, of course, it is perfectly true; that is, in the narrow sense of the word, you don't call acetic acid an oil; that is, in every-day life, acetic acid is not called an oil, and consequently to that extent it is justifiable. On the other hand, the practice in flotation matters is to call everything an oil which tends to show a selective adsorption for mineral as opposed to gangue. Now, that may or may not be a good thing to do, but it is the regular and established practice, and consequently when one is talking about flotation, acetic acid is an oil, and while it is perfectly legitimate anywhere else to say that acetic acid is not an oil—I should not classify acetic acid under ordinary conditions as an oil—it certainly is an oil under the established usage and customs of flotation matters, simply because it is better to call all things by the same name when they behave in the same way. In regard to the selective adsorption of mineral with reference to gangue, you get that with oils, with soluble frothing oils and with so called mineral frothing agents, as defined by Mr. Williams—they all behave in exactly the same way; in other words, they <sup>all</sup> show selective adsorption,

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and consequently they are all oils, and consequently under that nomenclature acetic acid is an oil and the statement is inaccurate. You can not judge a statement of that kind except with reference to the context, and it is perfectly true under some circumstances and it is absolutely false under others. That is why I prefer to classify that as a misleading statement.

Q. 13<sup>Q</sup>. Would you expect that air bubbles disseminated by a suitable agitation in the presence of a soluble frothing agent, would search out mineral particles from the ore pulp, pick them up and carry them to the surface, leaving the gangue?

A. I don't see how they could be expected to do anything else, because by your definition of a soluble frothing agent, it is going to have a selective action, and that seems to me simply—I may not have understood your question, but it seems to me like saying the thing right over and over again.

Q. 131. In these cases are the air bubbles in direct contact with the mineral particles?

A. Again that is the same question; they are not. Under those conditions you have—you might say—an oil layer—the oil layer you have is different, because it does not come out as an oil—you have a relatively oil rich solution in contact with the air throughout, and you do not have any contact between the solid particle and the air under these circumstances.

Q. 132. Is it possible to have direct attachment of your air bubble to a mineral particle?

A. Theoretically I think it is; that is, we know that

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in the case of so called minerals, zinc sulphide and lead sulphide, they do generally adsorb air markedly. The reason we know that is because they are not wetted readily by water, and since the air is adsorbed markedly, there is no reason why you should not have direct contact between the sulphide and the air, and there is no reason why under suitable conditions you may not have an air bubble in contact with the mineral and actually lifting it. On the other hand, you may not have that, if you have present in your water either an oil—either an insoluble oil or a frothing oil or a soluble frothing agent. In other words, the thing is perfectly possible theoretically; I should not think of disputing it. Whether it occurs in any given case or not is a matter to be decided with reference to that particular case.

Q. 133. When mineral particles are apparently lifted by the air, is it certain that that is really happening?

A. No, I don't think it is, because there is always a possibility that the mineral particles are not clean in the beginning; that they may have had on their surface either oil or greasy matter from somewhere, and that consequently under those conditions one was not dealing with the direct contact of air with mineral. That would all depend, as far as I can see, on the degree of care with which the experiment was carried out, and I should not be willing to accept the mere statement that one had a contact between air and mineral as conclusive unless the thing were shown to be

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so. It is perfectly possible that you may have it, but it is equally possible that experimental errors may come in. Even I can not do my experiments and make them come out right every time.

Q. 134. Have you any independent evidence to confirm your statement on this subject?

A. Yes. If you take a piece of mica and split it into two pieces or two plates; now, if you press those pieces together any time within three or four minutes, the thing will go back and make practically one piece of mica instead of two. If, on the other hand, you wait more than three or four minutes—say if you wait ten or twelve minutes, then you can not possibly press those two pieces of mica together and make them weld into one by any pressure that any ordinary man can exert with his thumb and forefinger; which shows that during the ten minutes that those fresh mica surfaces had stood exposed to the air, that something—a film of air or a film of water or a film of grease had condensed upon them, so that when you press them together you do not really bring the things into intimate contact.

Now, there is another rather interesting thing about that. Lord Rayleigh states that the film which forms <sup>fire</sup> on the surface of the mica conducts electricity, and therefore he concludes that it contains water; that is, in other words, that it is chiefly or partly moisture condensed from the air; that in the course of a few hours—I don't know how many—but in the course of a few hours, instead of having a conducting film on the sur-

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face of the mica which conducts electricity, you get a non-conducting film, from which he draws the conclusion that it is due to adsorption on the surface of the mica of grease or oily matters from the air.

Now, of course in view of that thing which we know in the case of mica and which can be determined experimentally and has been determined experimentally, it seems to me very doubtful whether any particle of mineral which has been exposed to the air, unless extraordinary precautions have been taken, should be free from grease or oily matter, and for that reason it seems to me very doubtful whether anybody has ever shown the actual lifting of a mineral particle by direct contact with air, although I am perfectly willing to admit the theoretical possibility. In fact, I would go further, and say that theoretically it is unquestionably possible, but one would have to consider in any particular case whether the man who did the experiment had taken enough precautions to prevent the contamination of the surface, which would certainly take place very readily if the particle was exposed to air.

Q. 135. Do you know of anyone ever having performed any such experiment, taking the precaution which you have described to avoid contamination of the particle?

A. I don't know of any experiments that have been performed where the necessary precautions have been taken.

Q. 136. Is it true, then, to say that in the agitation froth process, the froth, and the single bubbles, there-

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fore, consist of metallic particles held to air bubbles by direct attachment?

A. It is not true. In all those cases you have an oil layer or an oil rich solution in contact with the air, and the particles are in the oil film or at the oil-water interface, or in the oil rich solution, depending on which particular case you are studying. I do not see any possibility under any circumstances where you can have direct connection between air and a particle in the presence of any of these so called frothing agents, and I do not believe it occurs.

Q. 137. Do you consider the proposition correct or incorrect that the fundamental principles of flotation are air entrainment and the increased affinity of air for metallic particles in the presence of a frothing agent?

A. It is perfectly right to say "air entrainment" if one knew what it meant. If you mean that an important thing in flotation is the formation of bubbles containing air, that part of the statement is true. The other part of the statement, that an important factor in flotation is due to the increased affinity—

Q. 138. The increased affinity of air for metallic particles in the presence of a frothing agent?

A. The statement that the "increased affinity of air for metallic particles in the presence of frothing agents" is an important fact in the flotation process seems to me absolutely and hopelessly wrong because, as I say, you never do get, under these circumstances any contact between the air and the particle. If you

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did, it would be a very important and a very interesting thing, but you don't do it.

Q. 138½. If you were told that when a bubble lifting metallic—if you were told that when air bubbles lifting metallic particles, met the thinnest possible oil layer they dropped the particles, how would you account for it?

A. Well, I would account for it, I think in two ways: in the first place, I should account for it by saying that if the bubble hadn't any viscous film it would of course burst and the particle would be dropped back into the oil where it would either be held up by the bulk oil process, or it would not, just as the case might be. That would depend on the size of the particle. The other way of accounting for it, which seems to me to be simpler, is to say that I know that it is not so because I have seen a particle lifted up with an air bubble in a bubble holder through an oil film. I admit it is not an easy thing to do experimentally, and one might easily fail twice in three, but I have seen the particle come up. So that under this condition I don't quite see why I should be expected to account for its not coming up.

Q. 139. What would you call a froth made by agitation at about 1800 revolutions per ~~second~~<sup>minute</sup>, 80 c.c. of water at 70°, 16 gms. Broken Hill tailings, .6 c.c. 20% sulphuric acid and one drop of oleic acid, which would be between one tenth and two tenths of a per cent on the ore?

A. Well, I would much rather have that put in terms of oleic acid to mineral, because, as I have tried

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to point out, that is the only rational way of doing it; but of course that hasn't any bearing on the experiment. I should say there can be absolutely no question but that that would give you exactly the same type of froth that we have been discussing ever since we came here; that is a froth in which you have an oil layer or an oil-rich solution in contact with the air.

Q. 140. In your judgment would it be proper to call such a froth an air froth, meaning thereby that the air is attached directly to the mineral particles?

A. It would not be proper to call it that because that is not what happens; and it is a great deal better, it seems to me, to stick to facts.

Q. 141. Is it possible to obtain a so-called oil froth in which there are oil globules, with the mineral distributed entirely through the globules, with skins of dividing water partitions between the oil globules and with particles of air entrained between the globules?

A. I don't see any difficulty about doing that. Suppose you were to take the bulk ~~of~~ oil process and shake up the oil until you get some of the oil down in the bottom of the beaker, let us say, if we are doing it in a beaker, as oil globules. Now, these globules might or might not contain particles of mineral—it could perfectly well be arranged so they would, I imagine, so that all of these would. Down there, you have all globules containing mineral particles inside of them, separated by either thick layers of water, if you only had one or two globules, or by thin layers—which you could call films, in case you had a great many down under this condition. Now, I see no difficulty whatever

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in blowing in air,—I don't know that you could do it—I never tried it, but I don't see any inherent reason why you should not blow in a small amount of air, avoiding marked agitation, so that the air bubbles would cling to the oil and you would then have an oil globule containing mineral separated by watery films and containing air—did you say "entrained" or "entangled"—whichever it was, between them. Now, that is starting with a lot of oil. Of course, if you start with small particles, either a single particle with a little oil around it, or if one performed with a granulated particle, Cattermole effect, with oil around that, under this condition—under these conditions your granules would have particles with oil around them and no air. And now if you had enough of that and the ratio of solid to oil was not too high and if you got air entangled in them in the same or similar way, I see no reason why they might not float up to the top and give you, on the surface, oil globules with particles of mineral entirely inside the oil, with water films separating the globules and with air bubbles scattered around more or less frequently through the oil. I don't know whether I can do the thing experimentally, but it seems to me—that is I don't know it from my own personal knowledge—but I do not see any conceivable reason why it should not be done if anybody wanted to do it. I think I can do it myself if I had to.

Q. 142. Well, would such, a so-called oil froth be identical with the froth obtained in the agitation froth process?

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A. Why, no, of course not—absolutely not, different in every respect.

Q. 143. Is this so-called oil froth that you just described in one of the previous questions a true froth?

A. No, it is not a true froth at all, because it does not come under the definition as given. Of course every man has a right to make his own definition, but afterwards he has got to live up to it; and the definition that I made which I think is the definition that would be accepted by pretty nearly everybody—probably with slight changes in wording—I don't care about that—is that a froth is a closely packed mass of bubbles having a honey-combed structure with the cell walls composed of liquid films and the individual cells filled with air or other gas. Now, if anybody is going to be hypercritical I will modify that. Of course when I say, "honey-combed structure" I mean what anyone would under ordinary conditions. I do not mean that a cross section of one of those bubbles is actually hexagonal in shape as is the case of a honey-comb of a bee, but I am using the word "honeycomb" in the ordinary way in which the word is used.

#### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 144. Professor, you mentioned an article as having first attracted your attention to flotation, Swinburne's article?

A. I did.

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X-Q. 145. And I thought you had the article at the time?

A. I did.

X-Q. 146. May I look at it?

A. Certainly, with great pleasure. I supposed you had seen it.

X-Q. 147. The discussion in this article is of the so-called Potter-Delprat process, is it not?

A. I think that is what it is. I so understood it, although he carefully avoids putting it in that way. That is my recollection of the article, that he says he is going to discuss it from a purely scientific point of view without any reference to any definite—or without any specific reference to any definite process. As a matter of fact, however, I think your statement is perfectly correct.

X-Q. 148. I understood you to say during your testimony that Dr. Adolf Liebmann had said that a phenol when present in water in such proportion that it was not dissolved was an oil? Where did you take that statement from?

A. I did not make that statement in exactly that form. As I understood you, you read it that I said that "a phenol." My statement was that phenol—of course it comes to the same thing, but there are a number of substances which are phenols. I can give you that reference in a moment or two. I think I have it in my notes. You will find it in the third volume of the Miami transcript, page 1852. I think I quoted it correctly. I verified the quotation.

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MR. WILLIAMS: If your honor pleases, I would prefer to read over the deposition of Professor Bancroft before the cross-examination, thereby hoping to save considerable time.

THE COURT: That hope springs eternal. Well, it is five minutes of five and we will adjourn until 10:00 o'clock tomorrow morning.

WHEREUPON an adjournment was taken until Saturday, April 28th, 1917, at 10:00 a. m.

Saturday, April 28th, 1917, 10:00 a. m.

WILDER E. BANCROFT resumed the stand for further

#### CROSS-EXAMINATION

BY MR. WILLIAMS:

X-Q. 149. Reading from your testimony of yesterday, in your answer to Q. 34, you said, "Dr. Adolf Liebmann said that when you add a small amount of phenol, so that it is all dissolved in the water, it is a soluble frothing agent, but if you add an excess of phenol it is an oil, therefore of course would come under the head of partially soluble oils." I have read the part of the testimony of Dr. Liebmann in the Miami suit to which you gave me specific reference as authority for that statement, page 1853, and it seems to me that you have not quite accurately stated what Dr.

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Liebmann says; so I will call your attention to Dr. Liebmann's testimony, answer to X-Q. 249, and ask you if you wish to correct that statement. (Handing witness copy of testimony.)

A. He says that phenol is a soluble frothing agent, and he says here at the top of the page that an excess of phenol is an oil, and he says, in the answer to question 2051, "I say it is phenol as an oil." I don't see any reason for modifying that statement.

X-Q. 150. Well, the differentiation which occurs to

P. 3211, L. 13, insert "as an oil", and wherever he repeats it he always says", after (:)

X-Q. 151. Do you accept that correction?

A. No, I do not. In 2049 he says, "Now, that excess of phenol over and above the amount that will go into solution, in what condition does that exist? As an insoluble substance, as an oil; it exists as an oil." He does not say that it acts as an oil." I don't see any reason for modifying that statement.

X-Q. 152. Then I will read the full statement so that we may have a comparison. "X-Q. 2049. Now, that excess of phenol over and above the amount that will go into solution, in what condition does that exist?"

A. As an insoluble substance, as an oil. X-Q. 2050. As phenol or as some hydrate that exists there? A. It is an oil. Q. 2051. Does it still exist as free phenol, or does it form some combination with the water? A. I say it is phenol as an oil. Q. 2052. Well, this excess

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over and above what is in solution is still simply phenol?

A. Yes." I think that covers it?

A. I think it covers it, yes.

X-Q. 153. That is the correct reading of the testimony, is it not?

A. Absolutely correct.

X-Q. 154. Now, dipping a piece of galena, for example, into a particle of insoluble oil, some oil is removed by withdrawing the galena from the oil, is it not?

A. It is.

X-Q. 155. What is the condition of that oil; does it become attached to this metalliferous particle?

A. If you mean—what do you mean by what is the condition? It is oil.

X-Q. 156. What holds it to the metal particle?

A. It is adsorbed by the metal particle.

X-Q. 157. Does it adhere to the metal particle?

A. I should prefer to say that it is adsorbed by the metal particle because that is more accurate.

X-Q. 158. What is the thickness of the coating that you get around the metal particle in thus dipping it; does it—it gives you what measure of adsorption layer?

A. By adsorption layer do you mean the thickness or the force with which it is held, or what do you mean?

X-Q. 159. Well, we will take thickness?

A. The amount of oil that will be on the surface may vary with the conditions of the experiment from a very small amount up to an amount—a thickness which

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would drip off, depending on the way in which you hold it. I don't see any way that you could get a thicker layer than the amount that would drip off.

X-Q. 160. Would the amount that would not drip off be an adsorption layer?

A. I think you could call it that—that oil would be adsorbed.

X-Q. 161. All of it?

A. All of it, I think.

X-Q. 162. What is your authority for that statement?

A. I think I would prefer to quote myself as authority for it.

X-Q. 163. Is there any other authority?

A. For the existence of adsorption under the conditions that I have stated?

X-Q. 164. Yes.

A. I don't remember whether anybody who has written a book on colloid chemistry has discussed the specific case of oil and galena. I can not see why anybody should have taken it up, and I don't remember that they ever did.

X-Q. 165. That thickness of the oil layer that would not drip off would vary with the viscosity of the oil, would it not?

A. Yes.

X-Q. 166. With a viscous oil, would it still be an adsorption layer?

A. That would depend on how you looked at it. Personally, I should consider that as an adsorbed layer

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because the oil is adsorbed at the surface between the galena and the oil; and as long as the rest of the oil is there I think it would be less confusing to call it an adsorption layer. If you prefer to put in any other definition I would be glad to discuss it in terms of your definition.

X-Q. 167. Do you recognize any difference between adhesion and adsorption, as applied to the terms that I have stated?

A. Yes, adhesion and adsorption are two entirely different things.

X-Q. 168. I would like you to define the difference.

A. Adhesion is the holding together of two dissimilar substances, whereas cohesion is the holding together of two parts of the same substance. Adsorption is a surface condensation or concentration as the case may be, and of course involves adhesion, but the two are not identical. That is, you have got <sup>to eat</sup> to live, but eating is not necessarily living.

X-Q. 169. Well, can you point out the difference in the instances that I have given, where a coating of oil adheres to a metallic surface, and, as you put it, a coating of oil is adsorbed on the metallic surface.

A. When it is adsorbed, then of course it adheres, but the two are not the same, although both take place or may take place simultaneously; but as a result of the adsorption that substance adheres to the underlying particle.

X-Q. 170. Can it adhere without adsorbing?

A. I do not know, but I think not.

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X-Q. 171. Now, in the instance of a highly viscous oil, you would get a thicker layer, wouldn't you?

A. You would get a thicker layer, yes.

X-Q. 172. It would adhere to the metallic particle?

A. It would.

X-Q. 173. And, by reason of its viscosity, a thick, comparatively thick layer, would be obtained; is that right? *A. Yes.*

X-Q. 174. The adherence would be the result of a *force*, it not, or the result of the ~~molecular force~~?

A. It would result from the fact of the adsorption. If it were not adsorbed, as I said, I think it would not adhere.

X-Q. 175. But it would be the molecular force would it not, or the result of the molecular *force*?

A. I would prefer not to talk about molecular force, because there you go off into a realm where you can speculate as much as you like without getting anywhere. I prefer to stick right to the terms that I used, that it is adsorbed. Why it is adsorbed I do not know, but it is a fact that at the surface of any solid or liquid, you tend to get adsorption of a gas, or a liquid or of a solid as the case may be. And, that that adsorption is selective and varies with the nature of the solid, the liquid and the gas.

X-Q. 176. Can you give me an exact definition of adsorption?

A. Adsorption is surface condensation or concentration.

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X-Q. 177. THE COURT: Would you say it takes place within the solid, too?

A. You can have an adsorption of a solid by another solid. For instance, for polishing metal we often use rouge in water, and there the rouge acts as an abrasive and polishes the surface of the metal. If, by any accident you let the rouge get dry, you will find that it will adhere very firmly to the surface of the metal and will spoil the polish. You have another case of it, of a similar sort, in impure mercury, where mercury flours. That may be due to the adsorption of grease—perhaps you wouldn't want to call grease a solid—or you may have it with an oxidized film. The case I cited the other day of a dry glue with the glass, the glue could not pull the splinters out of the glass unless it were adsorbed by it. Of course one might say that dried glue is a liquid and not a solid, but in the case of the rouge you have an unquestioned solid.

X-Q. 178. MR. WILLIAMS: In that oil layer whether we have adsorption or an adhesion resulting from an adsorption with a viscous layer or with any layer, there would also be cohesion, would there not?

A. Certainly, between any two thicknesses or portions of the oil you will have cohesion.

X-Q. 179. That is between the molecules and like substances there is cohesion? Am I accurate?

A. I didn't say that, no.

X-Q. 180. Well, then, please define cohesion as you would like to define it.

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A. Cohesion is the holding together of two parts of a like—of the same substance. I did not say anything about the molecules; I dodge molecules wherever I can.

X-Q. 181. What are the reasons for your opinion that in the instance that I have given you there is a surface concentration of the oil?

A. Because under all circumstances so far as I know, where you have two surfaces in contact you do have an adsorption of surface concentration of something there. That is, so far as I know, no surface can exist without adsorbing greater or lesser amounts of something. What that will be depends on conditions. You may have a surface adsorption of a gas, of a liquid or a solid; but you have no surface that does not show a certain amount of condensation, so far as we know.

X-Q. 182. Now, in the instances that I have given you, what was the thickness of the layer in which adsorption occurred?

A. I do not know; your layer may vary from a very thin one up to a distinctly thicker one. I do not see that there is any way in which you can speak of the different thicknesses of your adsorbed layer without describing your terms a great deal more accurately than you have yet done.

X-Q. 183. Have you made any measurements of the thickness of the adsorbed layer of oil on metal?

A. I have not, but I can give you all the references to them if you want.

X-Q. 184. I have The Chemistry of Colloids, by W. W. Taylor.

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A. I recognize the book.

X-Q. 185. Will you take the statements in that book as fair statements of authority?

A. No, I will not; not unless they are verified, because the book is a very bad book, written by a man who did not know his subject and who has arranged his subject in the worst possible order. Anyone writing a book on colloids should begin with adsorption; while, if my memory does not fail me, he puts in a chapter on adsorption over towards the end of the book. It is written by a man who had very little knowledge of colloidal chemistry, who had done very little work. It represents an especially bad instance of hack work. Of course, I do not mean to say thereby that everything in it is wrong, because that would not be true, but you can not place any reliance on any statement in that book because the author put it there. If it can be checked independently, well and good.

X-Q. 186. I will ask you to read that short paragraph on page 26, "Thickness of Adsorption Layer."

A. Out loud?

X-Q. 187. No.

A. I have read it.

X-Q. 188. Will you accept that as authority?

A. As authority in regard to what? On adsorption layer?

X-Q. 189. Yes.

A. He is not talking about adsorption layer. There isn't any adsorption layer here. He is talking about the

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behaviour of water or any liquid, and not necessarily in the presence of gas or vapor, which would be adsorption; and the surface layer that he is discussing under these conditions is not the adsorption layer that you would have in case you had either vapor or gas. It is an entirely different thing.

X-Q. 190. Suppose you give me some of your authorities.

A. For what?

X-Q. 191. Thickness of the adsorption layer..

A. Certainly—hold on a minute. I said there wasn't any such thing as a definite thickness of your adsorption layer. I can give you the minimum values under certain conditions at which the adsorbed film can be detected, and I can give you various other values, but I can not give you any definite figure for the thickness of an adsorption layer, because there isn't any such thing.

X-Q. 192. I so understood it, but you can give some indication of it. Please do so.

A. Minimum values.

X-Q. 193. I think perhaps you had better start with the minimum values?

A. The minimum value that has been accurately measured as affecting the properties of the substance in question is of the general order of one one-hundred millionths of an inch, or three ten millionths of a millimeter.

X-Q. 194. Now can you give us the range of the adsorption layer?

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A. The ~~storage~~<sup>range</sup> of the minimum values?

X-Q. 195. No, the range of values within which the adsorption action is manifested?

A. No, I can't give you that.

X-Q. 196. How far can you go above the minimum?

A. I can give you, as I said, different minimum values; for instance I have here the smallest visible—the thinnest visible oil film is of the general order of one one hundred millionths of an inch. The oil film which is thick enough to change the surface tension of water is three times as thick as that. The film of albumin which is just thin enough to give you a so-called solid film on the surface is ten times as large as that, and we have other data of the same general order—those representing the minimum thickness.

X-Q. 197. And you are talking now of a film on the surface of water?

A. The figure which I gave there was for the thinnest film of oil on the surface of water which can be detected by optical means, and is one one hundred millionths of an inch, or thereabouts. I can give it to you in millionths of a millimeter, if you prefer.

X-Q. 198. I would rather have it in inches?

A. Well, in round numbers it is of the general order of one one hundred millionths of an inch, unless my arithmetic is bad.

X-Q. 199. And when you get to the amount of film which will affect surface tension, as I understand you, it is in what figures?

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A. Just about three times as large as the minimum one that you can determine.

X-Q. 200. And what is the book you are referring to, and the page, please?

A. The page from which I took those data is page 278 of the book to which reference was made the other day, Freundlich's ~~K~~ Capillary Chemie.

X-Q. 201. And that book is a book that you would refer to as an authority?

A. Oh, dear, no. I would not refer to any book as authority. I am merely quoting the references which he gives, and I am not quoting them on the authority of Freundlich at all. These are simply the measurements given by certain observers, and I shall be happy to give you their names if you like, and they represent their conclusions. I do not guarantee the accuracy of them in any way, but simply they are the best available information, and they are probably not very far wrong.

X-Q. 202. Is surface tension due to molecular force?

A. I suppose in a sense you can say that everything might be due to molecular force. I would not commit myself on the subject at all; I would simply take it that we have surface tension as a matter of fact, and I don't care at all how you get it. You see as a matter of fact you can get exactly the same results experimentally and quantitatively whether we consider that as something analogous to a surface film, like a rubber band, more or less roughly, or whether we consider that we are dealing with an internal pressure, the particles of the liquid

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tending to go to the center—those two things are fundamentally different conceptions, but they lead, as far as I know, to exactly the same numerical results in regard to surface tension, and you can take one or the other as a working hypothesis to account for it, to suit yourself. There is no way that I know of of distinguishing between those two hypotheses, and consequently it is a great deal better to take your facts as you have them, and not as they might be.

X-Q. 203. I did not put any hypothesis to you?

A. Oh, yes.

X-Q. 204. I put the simple question, whether surface tension was due to molecular force?

A. That is a hypothesis.

X-Q. 205. I ask you the question, is surface tension due to moelcular force?

A. I can't answer that—I don't know.

X-Q. 206. Is adsorption due to molecular force?

A. I don't know. That is merely a question of definition.

X-Q. 207. Well, that is enough.

A. Certainly.

X-Q. 208. Mr. Kenyon has called my attention to the fact that in that part of Dr. Liebmann's testimony which I quoted, I should have read the next question, commencing page 1853, X-Q. 2053. "It is nothing else; it is simply phenol? A. It possibly contains a trace of water. It is a remarkable thing that phenol by itself forms cresylate, melting at about 45 per cent;

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that is, it liquifies, but the part that is absolutely insoluble has the qualities of oil, you must remember, with the water." I have read that correctly, have I not?

A. You have read that correctly.

X-Q. 209. Now, has your study of the process that is here involved included—have you seen the process here in suit operated on a commercial or continuous scale, and if so, when and where?

A. You mean this agitation froth process?

X-Q. 210. Of ore concentration?

A. Well, I strolled casually through the plant of the Butte & Superior Company the first Sunday afternoon that I was here.

X-Q. 211. About two weeks ago?

A. It must have been Sunday the 15th, I think, and that is the extent of my knowledge of the technical process, if you can call that an extent.

X-Q. 212. Now, I show you an article printed in "Metallurgical and Chemical Engineering," dated June 1st, 1916, pages 1631 to 1635, entitled "Ore Flotation," a paper read at the joint meeting of both sections of the American Institute of Mining Engineers and the American Electro-Chemical Society, on May 12th, 1916, by <sup>W. D.</sup> Wilder D. Bancroft. Is that the paper that you read at that society at that time?

A. It is, or rather this article is based on what I said there. I do not mean to say that I said everything in the talk that is in here, or vice versa, but this article is an article based on that lecture, written up from my

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lecture notes, so that I imagine it gives substantially what I said at the meeting, but as I spoke from notes only, I would not want to guarantee that.

X-Q. 213. I notice at the end of the article the words "Cornell University." Apparently as though this were something that was written at the university and reprinted. Of course, I merely want to refresh your recollection about the matter?

A. Not at all. I always put Cornell University at the end of all articles that I write; I would do it even if I were to write an article out here before I went home—which I am not going to do, by the way.

X-Q. 214. Well, you wrote this?

A. I wrote this, certainly.

X-Q. 215. Now, I read from this article as follows—do you want to follow me?

A. Well, I should like to have a copy; it will be easier to follow it; in fact I should like to keep it, because I haven't a copy myself.

X-Q. 216. We can spare that one; you may have it.

A. Thank you.

X-Q. 217. "When discussing the theory of ore flotation people are apt to lay more stress upon surface tension in general and upon contact angles in particular. While this is entirely legitimate, it seems undesirable, because we cannot measure a contact angle with any accuracy, and because the actual existence of a contact angle is a matter of doubt." Have I read that correctly?

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A. You have.

X-Q. 218. Was that your opinion at the time that you wrote this article?

A. It was.

X-Q. 219. Is that your opinion now?

A. It is.

X-Q. 220. I will now read also from the article a foot note, referring directly to the part that I have read: "Rayleigh Scientific papers, three, 354, 1902." That is correct?

A. That is correct. I should like to add one statement, which may or may not have a bearing on this. I wrote this article, but I did not read the proof of it, so that it is possible that there may be some typographical errors. I don't know that there are.

X-Q. 221. From page 634 of the article I read as follows: "So far we have been considering the case where we have a fair amount of oil. If we cut the amount of oil down (almost to the vanishing quantity), another factor comes in, namely, air flotation. When sufficient quantities of oil are used the air floats the oil and the oil floats the ore. The ore is enclosed in a drop of oil having the properties of the matter in mass, and sinks to the bottom of the drop of oil, distorting it to a greater or lesser extent. If the amount of oil is decreased sufficiently we no longer have an oil drop surrounding the particle of ore, but an oiled particle, the lower part of which is, or may be in contact with water, while the upper part is in contact with air. We are, therefore, getting air effect in addition to the oil effect.

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*I do not know the relative importance of these two effects, but it has been claimed—and disputed—that modified air flotation is very much greater than the other.”* Have I read correctly from your paper?

A. You have read correctly.

X-Q. 222. Did that at that time represent your views, your opinion?

A. It did.

X-Q. 223. Is that your opinion now?

A. I think I would word that a good deal differently now.

X-Q. 224. I will read further, and immediately following what I read: “In the Wood & MacQuiston processes there is no doubt that the separation would be more effective if it were possible to cover the ore particles with a thin covering of stearin, leaving the gangue particles uncoated. It is very difficult to wet the stearin coated commercial copper and aluminum powders, and it is therefore very difficult to make them sink under water. In modern processes of ore flotation using very little oil per ton, you get a thin coating on the ore, analogous to the stearin coating on the copper or the aluminum powder. It is possible that the air film may surround the oil particle completely, so that the oil does not come in actual contact with the water. In that case we are back to a straight air flotation of the oiled particles. This point calls for further study, because, if established, it will have a very important bearing on the future development of the subject.” Have I read correctly from your article?

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A. You have.

X-Q. 225. Did that then express your views?

A. It did, but it does not now.

X-Q. 226. Does it now?

A. It does not.

X-Q. 227. I will read further, immediately following: "It is under these circumstances that the addition of more oil causes the ore to cement together and to sink. The reason for this will perhaps be seen more easily if we consider the analogy of sand and water. When enough water is mixed with sand you get a quicksand, over which it is unsafe to walk. With only a little water you get a plastic mass over which it is a pleasure to walk and out of which children can make forts and pies, etc.,"—

A. I will endorse that still (laughing).

X-Q. 228. "When the sand dries out, more air gets in between the grains, and walking becomes hard, though the sand is by no means dry from a chemical point of view. When the amount of oil around the ore particle is sufficiently small, the air gets in and makes a froth possible; with more oil you get a plastic mass; with still more you get the bulk oil process." Have I correctly read from your article?

A. You have.

X-Q. 229. Did that represent your views at that time?

A. In a sense, yes. It might be said more accurately to represent what Dr. Grosvenor told me the afternoon before the lecture.

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X-Q. 230. Does it represent your views now?

A. It does not.

MR. WILLIAMS: That is all.

#### RE-DIRECT EXAMINATION.

BY MR. SCOTT:

R-Q. 231. Have you any comment to make, Professor Bancroft, on the passages from this article which were read to you, about ore flotation?

A. I think the simplest way of dealing with this article is to say that it represented my views at the time I wrote it; that all parts in it which are inconsistent with the testimony that I gave yesterday are wrong to the best of my knowledge and belief, and very likely certain other portions in it are also wrong. With those exceptions it represents my views today.

R-Q. 232. Can you describe any experimental proof of the existence of viscosity in the surface film?

A. That can be measured in different ways. If you suspend a needle by a fine string and let it go down into the mass of a liquid, and then cause it to swing by means of a magnet or in any other way, you will find that you get a definite rate of damping, as it is called, or slowing down of the swing of the needle. If you do that same thing in the surface of a solution where the surface tension is lower than that of the pure liquid, and where the surface film is supposed to have an increased viscosity, you find that the needle comes to rest very much more quickly, showing that there is a distinctly

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greater resistance to the swinging of the needle. That experiment can be modified in all sorts of ways, but it comes to much the same general thing. The existence of a film at the surface having a lower surface tension than the mass of the liquid can also be shown very easily, because if you produce suddenly a fresh surface from somewhere in the mass of the liquid, that would then give you, on a momentary reading, a surface tension corresponding approximately to that of the concentration in the bulk of the liquid; it won't do it absolutely because it would be changing right along; consequently you would expect to find, if you made a rapid measurement of the surface tension of a fresh surface, say of a saponin solution or a soap solution, that it will be higher than if you measured it on an old solution [I can give you some more data in regard to that if you wish it. These data are on page 56 of the same book to which reference has been made before, Freundlich's Kapillar Chemie. These are determinations at room temperature of a saponin solution; the value of the surface tension of a fresh surface is about 73, while the surface tension of water is about 75; it is nearly up to the value of pure water. The value of an older surface is 52; thus the difference between the surface tension of the mass of the liquid when measured as rapidly as you can, and the surface tension of the surface film is the difference between 73 and 52, showing, you see that there has been a concentration of the saponin in the surface film. There are other data here, but that one will do as an illustration.

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MR. SCOTT: That is all.

R-Q. 233. THE COURT: When did you commence lecturing on flotation?

A. In the autumn of 1912, and I have been carrying that out, a little under a lecture to a little over a lecture on flotation ever since then.

RE-CROSS-EXAMINATION.

BY MR. WILLIAMS:

RX-Q. 234. Just one part of your testimony here I don't quite understand. On page 1092 in describing a certain experiment you say that the materials that you used, you were told contained 1% mineral in one experiment, and in another experiment that it contained 65% mineral. Do you mean the metal or the metaliferous mineral?

A. I was told that in both cases the content was 1% mineral and 65% mineral. What it really was, I said I didn't know.

RX-Q. 235. Of course you know it is customary to state the values in the metal, as for instance 1% zinc sulphide, would be .66% zinc; and these values are customarily stated in the metal, and we have to add to that what the sulphur would add. You did not do that in this instance, did you?

A. I don't think that can be true. If that were true of the concentrates, the concentrates would be pure zinc sulphide. I don't know—the figure that was given to me in both cases was 1% mineral and 65% mineral.

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Whether it was that or whether it was anything else between 100 or one-tenth of 1% I have absolutely no knowledge. I didn't analyze them.

WITNESS EXCUSED.

MR. SCOTT: Mr. Williams has submitted to me a form of agreement that we are agreed upon as to the manner of presenting this testimony regarding mill operations. I will just read it as it is written, I think, and will let it go into the record:

"We are willing to enter into a stipulation with the defendant respecting the testimony of Mr. Dosenbach and other witnesses with respect to operations at the Butte & Superior plant to the following effect:

"We are to be furnished with a flow sheet of the defendant's mill with respect to any operation about which the witness is to testify.

"We are to be permitted to inspect the mill in order to see how the plant is operated, so as to ascertain the source of the important details from which determinations are to be made.

"We are to be shown whatever typical original reports of the different steps in the operations and of different characters and kinds of original reports and compilations thereof we demand.

"After which Mr. Dosenbach and other witnesses as to operations and results at the Butte & Superior mill may testify to compilations made up by the witness and from data from other sources than his own personal

knowledge, provided the defendant undertakes to furnish the original and best evidence as to anything so testified to by the witness that we demand, and if the defendant does not do so the testimony not thus justified shall be stricken from the record:

"Provided that either party may produce witnesses as to regular operations and results at other mills than that of the Butte & Superior without producing the original or best evidence if such witness has inspected the operations in question and the results and has knowledge of the details derived from inspection of the regular reports of others made at the time."

And we are mutually agreed to enter into that arrangement.

THE COURT: The record may show that.

MR. GARRISON: I only want to say, in connection with this stipulation, your honor, that has just been entered into, that we wish to advise counsel on the other side that if they propose producing Mr. Dosenbach or any other witness with respect to the Butte & Superior mill and its operations we shall require sufficient notice and opportunity to inspect the mill within a reasonable time before the testimony of the witness, so that they may not be surprised that we object if we had not been given that reasonable opportunity. I think it is proper to say that at this time.

MR. KREMER: In pursuance of the notice just given, we desire to state that we will produce Mr. Dosenbach as a witness and under the stipulation just entered into certain matters would be necessarily available to you, and you desire an inspection of the mill.

We now tender you that privilege, and if it would be satisfactory, and satisfactory to the court, you may make that inspection today, this afternoon.

MR. GARRISON: Oh, we could not possibly make it in so short a time as from the adjournment of court. We shall need a very much longer time than that.

THE COURT: I suppose they will allow you to go in any time.

MR. GARRISON: He said today.

MR. KREMER: Yes.

MR. GARRISON: But you see our men who are at all available will be here in court until something like four or five o'clock.

THE COURT: I don't suppose they will limit you to one day.

MR. GARRISON: He said today.

MR. KREMER: My statement carried with it the suggestion that they might take this afternoon if it would save time. I have no doubt your honor would be willing they should take it.

MR. GARRISON: We do not want to be limited to any brief time. When do you propose to produce Mr. Dosenbach?

MR. KREMER: Monday.

MR. GARRISON: Can we have the inspection on Sunday?

MR. KREMER: Yes, I think so. I do not want to say that they can have it and then have a part of the mill shut down.

MR. GARRISON: We can't possibly do it in two or three hours.

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MR. KREMER: Have all day tomorrow.

THE COURT: Haven't you had an inspection?

MR. GARRISON: No, sir.

MR. KREMER: The mill will be running all day tomorrow.

MR. GARRISON: Then we may have the inspection tomorrow?

MR. KREMER: Any time you please. Will you designate who will make the inspection for you, and the time?

MR. GARRISON: I will give all of that after recess; I will fix it at lunch so as not to keep the court now, while we confer. Is that satisfactory?

THE COURT: Yes.

E. W. ENGELMANN, recalled on behalf of the defendants, having been previously sworn, testified as follows:

#### DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Mr. Engelmann, will you first state what records, and what is the extent of the information you have with you, so we will know before we start.

A. I have the result, the tonnages, the assays and the amount of oil used for every day since the beginning of operations in 1914.

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Q. 2. THE COURT: Has this witness been on the stand before?

THE WITNESS: Yes, sir.

Q. 3. THE COURT: What company are you from?

A. The Ray Consolidated Copper Company, Hayden, Arizona.

Q. 4. MR. SCOTT: I think you stated your employment and education when you were on the stand before, didn't you?

A. Yes, sir.

Q. 5. Now, you—if you were asked about the details of any particular day that occurred in these quarterly periods you can give that information, can you, as to the particular days?

A. Yes, sir.

Q. 6. Regarding the amount of oil or other factors?

A. I can.

Q. 7. What kind of material do you treat by flotation at the Ray Consolidated Copper Company?

A. We have two different products; one we call our retreating plant feed. It consists of a concentrate made on the vanner. The other is our slime vanner tailing, which is the tailing from the slime vanners.

Q. 8. About what tonnage do you treat per day?

A. We treat approximately 7,000 tons of slime vanner tailings per day and 350 tons of retreating plant feed—that is, by flotation.

Q. 9. Have you a summarized statement of the operations on these various concentrating products?

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A. I have. Do you want it for months or quarters or years?

Q. 10. Quarters I think will do to start. Will you just read the title of the paper you are going to refer to, so we can identify it?

A. "Ray Consolidated Copper Company, Hayden plant, Flotation Operations Retreating Vanner Concentrate Products."

Q. 11. Now what period of time does that statement cover?

A. From the last quarter of 1914 until the first of April, 1917.

Q. 12. You were in charge of those operations throughout this period or were familiar with them?

A. I was in charge of the operations throughout the entire period.

Q. 13. The first column there of this tabulation sets forth the total tons treated by flotation in each of the periods mentioned, I take it, from the heading?

A. It does.

Q. 14. The second column is the assay of the copper in the heading. Now the No. 2 columns there, they are the tonnage and the copper assay of the flotation concentrates?

A. They are.

Q. 15. Now, under the heading "Flotation" you have "Copper Recovery." Will you explain the heading, the average of those two columns?

A. Under the "Copper Recovered" we have "Appar-

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ent" and "Estimated," but in this particular case we derive our flotation tonnage of concentration from our ratio of concentration which is derived from our assay. So consequently our apparent recovery and estimated recovery are both derived from the formula as given in one of the engineering journals that we adopt throughout all our plants and are practically the same.

Q. 16. Now, "New Oils Per Ton." The heading of the next column there: I take it that simply refers to the actual measured or weighed amount of oil that is fed into the pulp per ton of solids in the pulp?

A. Yes, sir.

Q. 17. Now, we come to the heading "Oil Assays." Will you explain that? "Flotation Heads, Including Circulation <sup>new</sup> Loads"?

A. The column "Flotation Heads, Including Circulating Loads," represents the amount of new feed plus the circulation tonnage against the amount of new oil, plus the circulating oil. That actually represents the pounds or per cent of oil in the total feed. The next column, the "Concentrate Assay," represents the per cent of oils that go to our final installation in the concentrates; and the third column represents the per cent of oil that is in our tailings, going to waste.

Q. 18. How do you measure the circulation tonnage?

A. These circulation tonnages are measured at intervals of every hour in special tubs built for measurement. These tubs are 6 feet in diameter and approxi-

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mately 5 feet high. We run the total feed into these tubs for a period of two or three minutes and take the per cent of solids at the same time we run the feed into the tub, thereby referring to the table, we have compiled, we get the tons of solids per day circulating.

Q. 19. You maintain a steady and uniform feed from day to day?

A. We do.

Q. 20. How are your circulating loads sampled and determined for oil analysis?

A. I can best explain that by reading our method.

Q. 21. Before, <sup>that</sup> possibly it would be better to explain the arrangement of the flotation plant. Have you any sketch that will serve for a flow sheet?

A. I have. I submitted one the last time for this plant, but I have another one here.

Q. 22. You gave one to counsel the other day?

A. No, I didn't get it. Here is one here, though.

Q. 23. What one are you going to use to put in evidence?

A. There is one in evidence already. (Exhibit No. +5.)

Q. 24. Now, I think you commented on this some the other day, but I think in order to get this clearly before us you might briefly refer to it again. Maybe if you put it on the desk the court could see it at the same time you are explaining it.

MR. WILLIAMS: I will lend your honor my copy.

A. The original feed goes into a small pump sump,

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and is pumped from there into the back of the first emulsifier. We have two emulsifiers in series. The discharge from the emulsifier is evenly distributed between five cells in multiple. These are Janney and mechanical flotation machines. And we make a finished concentrate on the five cells in multiple. The tailings from each individual cell in multiple join as one product and go to a series of five cells in series. The froth or middlings from these five cells in series goes back and joins our original feed, this getting to the head of the first emulsifier. The tailings from the last cell in series go to waste. The oil is added at the sump, where the original feed and circulating load go to the pump. Now we will come back to our question as to how the circulating loads are sampled and determined for oil analysis.

Q. 25. Will you make an indication on here as to the position?

A. Yes.

Q. 26. If you wish to, then we will have it all on the one exhibit.

A. "Method for Sampling and Determination of Oil in Pulp Used at Ray Consolidated Copper Company, Hayden Plant. Hayden, Arizona.

"Sampling. Samples are taken by hand in a metal sample cutter. The form and principle dimensions are as follows: The body of the cutter is cylindrical in shape approximately four inches in diameter and eight inches high. The cutter is held in hand by a loop handle similar to the usual tin cup handle. Opposite the

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handle is placed a spout extending at the top nine inches from the bowl and tapering from this outer edge to the bottom of the bowl with parallel sides one inch apart.

"In sampling this cutter is moved across the stream of pulp at such a rate as the sampler knows by experience will furnish a sample containing approximately one hundred grams of solids. This sample is transferred to a white enamel pan and brought to the laboratory for test.

"Determination of oil: The samples are immediately filtered upon receipt in the laboratory. This is performed in a Buchner funnel with suction. The pulp still moist upon the filter is then treated with successive small portions of chloroform which almost completely removes the oil, the latter being caught in the filter flask in chloroform solution.

"The chloroform is displaced upon the filter contents with water and the pulp is removed to a low temperature drying oven (temperature 140° F) and dried over night.

"The chloroform solution of the oil is separated from the water in a separatory funnel and placed in a small weighed flask. The chloroform is then distilled from the flask through a deflegmation head and recovered.

"When the distillation of the chloroform is almost completed, the flask is removed and the evaporation of the remaining choloroform accomplished by very gently warming with a soft flow of air into the flask. After cooling, the flask and contents are weighed and weight of oil noted."

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"When dry the pulp is weighed and thoroughly mixed by rubbing in a glass mortar. Thirty grams are taken for extraction dry in a Soxhlet extractor and after extraction the oil recovered is weighed in small flasks, the chloroform being removed by evaporation as with the oil extracted wet.

"The weight of oil extracted dry, is calculated to the equivalent for the whole sample and added to the amount previously recovered.

"The percentage of oil in dry pulp is then calculated from the total weight of oil and the weight of solids."

Q. 27. MR. WILLIAMS: Now, you have read that from a document which you had before you. Did you write that yourself or dictate that?

A. No, sir; that was dictated by Mr. Johnson, our oil expert.

MR. WILLIAMS: I suppose he knows more about that particular thing than you do, and you thought you would rather have his views?

A. Absolutely.

MR. SCOTT: If you object to it, I am not at all particular.

MR. WILLIAMS: No, I do not object.

THE COURT: What is this?

THE WITNESS: Analysis of oil determination.

MR. WILLIAMS: It is highly technical. I wanted it to appear that he was not testifying to it, but was reading what his oil expert said, to which I have no objection.

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Q. 28. THE COURT: This is the oil in the circulating load?

A. Yes, sir, and in the concentrates and in the tailings.

Q. 29. MR. SCOTT: And at what point are those samples taken for oil analysis, referring to this flow sheet? You might place a letter at each place you sample so that we will know.

A. "A" represents the tub where we measure our circulating load. "B" represents the point at which we take our sample for oil determination in our concentrates. "C" represents the point at which we take our determination for oil analysis in our tailings.

Q. 30. How do you measure the new oil that you add? I think you said at the pump sump.

A. It is added at the pump sump, but it is measured by a circular tank which has a reservoir, and we have a gauge glass graduated in eighths and quarters and halves and inches; and these are read at intervals of each hour, and the oil is fed with a mechanical feeder. These oils are checked against our total oil consumption for the month in our large storage tank out of the mill.

Q. 31. Will you state what quantities of oil you have used during the period flotation has been operated—I mean the range of quantities and when you changed from one quantity to another—that is, any marked change. I see up to the end of 1916 your quantities ran quite uniformly. Then beginning with 1917 they increased.

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A. Well, for the last quarter of 1914 to the end of the year 1916 our oil has only varied from 3.22 pounds per ton at the minimum to 5.28 pounds per ton maximum, for that period of time. After the year 1916, beginning January, 1917, we used 20.02 lbs. per ton, and in the month of February we used 18.77 lbs. per ton. From then to March we used 21.19 lbs. per ton.

Q. 32. Referring to the columns giving the assay of the concentrates and tailings and recovery, will you state in a general way how the results that you have obtained since January 1, 1917, compare with those prior thereto?

A. For the years and quarters previous to 1917 we have maintained a slightly better grade of concentrates than we did to the year 1917. Our tailing has been—Well, for the year 191~~X~~<sup>4</sup> we made a .617 tailing; for the year 1915 we made a .502; for the year 1916 we made a .375 and the year 1917, when using excess oil, we made a tail of .412. That is, including the month of March, Now, in the year 1914 we made a 92.94% extraction using 4.31 lbs. of oil per ton. The year 1915 we made 93.43% extraction using 4.21 lbs. of oil per ton; the year of 1916 we made 94.69% extraction using 3.36 lbs. of oil per ton, and for the first quarter or up to the first of April of 1917 we made 95.42% extraction with 20.1 lbs. of oil. Our extraction for the year 1917 has been the highest we have maintained since the beginning of operations.

Q. 33. How many pounds of copper per ton does the

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difference between 94.69% recovery in 1916 and 95.42% recovery for the first quarter of 1917 represent?

A. Well, according to my figures I have saved for the year 1916, 105 lbs. of copper per ton, and during the year 1917 122 lbs. of copper per ton.

Q. 34. That is 17 lbs. more in 1917?

A. Seventeen pounds more.

Q. 35. Per ton?

A. Yes.

Q. 36. Now, I notice that in the first quarter of 1917 you treated 28,913 tons. That would be a saving of 17 lbs. of copper for each ton in 1917 as compared with 1916, on the basis of these two recoveries?

A. Yes, sir.

Q. 37. About how much additional expense is involved in this extra oil you are using; about how much does that cost additional?

A. Well, we changed our oil proportions. Previous to the year 1917 we were using—well, we were using 75% of Barrett's No. 4 and 25% of fuel oil. That was the general trend of operations during that year. And, during the year 1917 we changed our oil to 90% fuel oil and 10% Barrett's No. 4. Now the Barrett's No. 4 is our expensive oil and our fuel oil is very cheap oil, but as far as the cost of oil per ton, I really have never figured it. Our fuel oil only costs us  $3\frac{1}{2}$  cents a gallon and our Barretts' No. 4 costs 36 cents a gallon, so we have used quite a large proportion of the fuel and cut

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down on the Barrett's, thereby cutting down our oil cost considerably—that is, the mixture.

Q. 38. What different kinds of machines have you used, and what were the tonnages when running with 20 lbs. of oil or over, during the first quarter of this year?

A. That is, you are speaking of the machines used in the retreating vanner concentrates?

Q. 39. Yes, confine it to that for the present.

A. We have only used the one machine on vanner concentrates and that is the straight Janney Mechanical Machine.

Q. 40. What kind of apparatus did you—do you use in treating the slime vanner tailings?

A. Well, we have three different kinds of machines. Our plant is composed principally of the Janney Mechanical Air Cell. It is similar to the mechanical machine only it has the air basket in the spitzkasten. Then we have what we call a straight air machine which is similar to the Inspiration type machine.

Q. 41. You may describe that briefly, the straight air machine.

A. I have—

Q. 42. (Interrupting.) I think the description will be enough without any drawing.

A. I have the drawing here if you want it. It is simply a long, rather narrow machine. The compartments are approximately three feet square and we have 16 cells in series.

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Q. 43. How is each cell made; what is its construction, how do you put the air in it?

A. Each cell has a filter medium at the bottom.

Q. 44. A porous bottom of some kind?

A. Yes. And the air is injected through this porous bottom and coming in contact with the pulp, and each cell has an overflow launder for the concentrates, and the tailings from one cell go to the next, right down through the 16 cells, until we have the final discharge at the last cell, and this total concentrate is considered one product, our ~~regular~~ <sup>rougher</sup> concentrate; it is recleaned in six cells of similar type, a recleaner. The tailings from this cleaner come back to the ninth or the middle part of the roughing machine.

Q. 45. Have you got the diagram of flow sheet of that?

A. I have, right here. These are separate platforms, numbered 1 to 16.

The feed comes in at the head of cell No. 1. From that cell we receive a concentrate and the tailings go to No. 2 and No. 3 and No. 4 and on until we get final discharge from cell No. 16, which is the tailings to waste. The concentrate passes from all these cells combined as one product and goes to our retreating machine, which is the same machine only six cells in series. The concentrate from the six cells in series or the retreating machine goes out as a finished product. The tailings come back to cell No. 9, or practically the middle of the roughing machine.

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Q. 46. Where is the oil added to the pulp in this air machine?

A. It is added with the pulp at the head of No. 1 cell.

Q. 47. And where are samples taken for oil, assay, etc.?

A. The sample for oil assay is taken—"A" would be right in the cleaner tailings, circulating back, and "B" would be the concentrate product from the cleaning machine. I think we have an assay on out tailings in that machine. Yes, I have one. "C" is the assay of the tailings which goes to waste.

Q. 48. Now, you have other machines in the slime production you said?

A. Yes.

MR. SCOTT: I think I will offer this in evidence, this being entitled "Ray Consolidated Copper Company, Air Machine Treating Slime Vanner Tailings".

The paper admitted in evidence and marked DEFENDANT'S EXHIBIT 149.

Q. 49. Now, if you will describe the other machine.

A. Our main installation treating plant treats 7000 tons of slime vanner tailings per day, the concentrate of the Janney Mechanical Air Machines. We have the flow sheet of that which is somewhat more difficult to follow than the previous flow sheet submitted.

Q. 50. You might produce that flow sheet, please.

(Witness produces the sheet.)

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Q. 51. What tonnage passes through that air machine you just described?

A. We treat from 300 to 415 tons, I think, per day.

Q. 52. Per day?

A. Yes, sir.

Q. 53. And this is by far the larger part of the slime plant?

A. This is practically the whole slime plant outside of the air machine. This set of machines treat practically 7000 tons of ore per day. We have two pyramids.

Q. 54. Just explain how you use that word "pyramid".

A. Well, it consists of one cell above the other, the original feed coming into the first row of cells, the tailing from that row of cells goes to the next row and the tailing from that to the next one, and the tailings from the last row, to waste. Just four machines in series, one above the other.

Q. 55. And that machine at the ridge, part of the tailings from that go each way, part goes down to the machine on one side and part to the machine on the other?

A. Yes, equally divided to both sides of the pyramid.

Q. 56. And what does each of these circles with an "X" in it, represent?

A. The machine, represents one row of machines.

Q. 57. The Janney agitating type machine?

A. Mechanical air machine.

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Q. 58. You have written on this drawing eight rows of cells. I take it that this drawing simply represents one row?

A. Yes.

Q. 59. Have you a photograph of it?

A. Yes, I have. There is the side.

Q. 60. Altogether how many of the Janney cells are there in this whole system?

A. There are 140 roughing cells and 45 cleaning cells.

Q. 61. Now, will you describe the flow of the pulp?

A. The feed and oil go to two emulsifiers.

Q. 62. Where are they?

A. They are at the head of the pyramids in multiple.

Q. 63. Represented by this machine, that box there?

A. No, no, they are in a pit, below the pyramid, and the discharge from the emulsifier goes to elevators which elevate the feed up to the first row of cells of the pyramid. Our original feed goes to the first row, and from there the tailings is distributed evenly to both sides; it goes to another row. The tailings from the second row go to the third row, and the tailings from the third row go to the fourth row, and the tailings from the fourth row go to waste. The concentrate produced by the first, second and third rows make up what we call the rougher concentrate. The concentrate from that fourth row circles back to the head of the elevators which feed the first row. The rougher concentrates go to two elevators and are lifted

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P. 3543, L. 12, "the same percentage of water in the feed ;  
and " after " are "

primary cleaners go to one elevator and from there through 5 multiple cells followed by five multiple cells, followed by five more multiple cells, and the tailing from the first five go to the second five, and from the second five to the third five, and the tailings from the third five go back to the head of the primary cleaning system. The concentrate from the secondary cleaning machines go to filters as a finished product.

Q. 64. About how fine is this material that you speak of that is treated in the slime plant?

A. Approximately two per cent on a 65 mesh, and seventy per cent through a 280 mesh.

Q. 65. How about the material treated at the retreating vanner concentrate; about what is the screen analysis of that?

A. 6.12 per cent on a 65 mesh and 45.61 through a 280 mesh.

MR. SCOTT: I offer the first tabulation referred to by Mr. Engleman, the one entitled "retreating vanner concentrate products?"

Tabulation admitted in evidence without objection and marked DEFENDANT'S EXHIBIT No. 150.

Q. 66. Have you a tabulation of the operations of treating the slime vanner tailings by flotation?

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A. I have.

Q. 67. What period of time does this tabulation cover?

A. From the second quarter in 1915 to March 26th, inclusive, 1917.

Q. 68. I notice on this tabulation that beginning in the month of January, 1917, the amount of oil was increased. Will you just briefly compare the recoveries and assay of the concentrate before and after the increase in the amount of oil?

A. During the year 1915 we consumed 1.71 pounds of oil per ton. Our tailings assayed .572, which would indicate an extraction of 38.2. During the year 1916 our consumption of oil was .85 pounds per ton and the tailing assay was .419, indicating an extraction of 45.64. During January 17th and 18th, 1917, our coal tar consumption was 20.3 pounds per ton and our tailing assay was .465, with an indicated extraction of 43.56. During the month of February 8th to 28th, a period of 20 days, we consumed 20.1 pounds of oil per ton, maintaining a tailing of .375, with an indicated extraction of 45.25.

Q. 69. Now, what kind of machines were those operations conducted in for those two periods January 17th and 18th, and February 8th to 28th?

A. For the period of January 17th and 18th, we made the runs with our pyramid installation, that is, the machines treating our big flotation tonnage. The period between February 8th and 28th inclusive, we made the runs on the air machine which was described previously.

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Q. 70. What makes the difference between the grade of the concentrate on January 17th and 18th, as compared with February 8th to 28th?

A. On January 17th and 18th during the run our flow sheet was practically the same it is ordinarily, as we had two recleanings, a double system of cleaning; but for the period February 8th to 28th the air machine is so arranged that we get only one cleaning, and we maintain a concentrate equally as high as our normal grade of concentrate from the primary cleaner: that is to say, the normal operation in previous years from the primary cleaner concentrate was an average between eleven and a half and thirteen per cent.

Q. 71. Then all these entries after the first, during the year 1917 represent operations with one cleaning?

A. No.

Q. 72. Will you state just which ones represent one cleaning and which represent two cleanings?

A. Well, January 17th and 18th, there were two cleanings. February 8th to 28th there—that was only one cleaning. March 1st to 14th there was only one cleaning, and March 15th to 17th there were two cleanings; March 20th to 26th were two cleanings. Now the result: On January 17th and 18th and February 8th to 28th and March 1st to 14th the results were obtained with one oil, while the results from March 15th to 17th and March 20th to 26th were obtained with another oil. They were both mixtures, both of these oils, or was it a single oil?

A. March 17th and 18th, February 8th to 28th.

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March 1st to 14th were obtained with straight coal tar. For the other periods, March 15th to 17th were obtained with fuel oil principally, and a small amount of Barrett's, and the results from March 20th to 26th were obtained with flotco No. 20, and flotco No. 21. I have an explanation of the machines, how many cleanings and the product received at the bottom of the report.

MR. SCOTT: I offer this table entitled "Ray Consolidated Copper Company treating slimes vanner heading and slime vanner tailing."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT No. 151.

MR. SCOTT: I offer the flow sheet referred to by the witness, entitled, "Janney Mechanical Air Cells of Pyramid Installation Treating slime vanner tailings."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT No. 152.

MR. SCOTT: I offer in evidence a photograph of the pyramid machines referred to by the witness.

Photograph admitted and marked DEFENDANT'S EXHIBIT No. 153.

Q. 73. Will you describe any experiments you have performed with different amounts of oil and what the purpose of performing those experiments was?

A. We performed experiments using different amounts of oil both for the retreating plant feed and

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our slime feed, and the purpose of those was to see if it was possible to maintain nearly the same results by using the different quantities of oil. On March 30th and 31st and April 1st, a period of three days, we treated by flotation in our retreating plant feed, using an oil mixture of ninety per cent fuel and ten per cent Barrett No. 4. We treated 1125 tons with 22.24 pounds of oil per ton, and made a concentrate of 21.48 per cent copper and a tailing of .32 per cent, with an indicated extraction of 96.14 per cent. During the period April 3rd; 4th and 5th, on our retreating machine, using the same oil mixture, 90% fuel and 10% Barrett No. 4, treating 1133 tons, we consumed 11.27 pounds of oil per ton and maintained 21.28 per cent copper concentrate and .290 per cent copper in the tailing, with a 96.67 per cent extraction. On March 30th, 31st and April 1st, treating our slime vanner tailing with straight coal tar, treating 795 tons, consuming 22.41 pounds of oil, we made a tailing of .375 per cent copper, an indicated extraction of 47.63. During the period April 3rd, 4th and 5th, while treating our slime vanner tailing, using straight coal tar, treating 772 tons of feed and consuming 11.2 pounds of oil per ton we maintained .366 per cent copper in tailings, with an indicated extraction of 46.15.

Q. 74. How do these results compare metallurgically with the larger and smaller quantities of oil?

A. Well, we maintain on our retreating machines month in and month out approximately 96 per cent extraction, which corresponds very closely with the ex-

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traction made on these runs. On our slime feed we maintain for months at a time between 40—42 and 46 per cent extraction.

Q. 75. When you say you maintain you refer to operations before the first of January, 1917?

A. Before the first of January, using small amounts of oil.

Q. 76. Yes.

A. Now, during these runs the operation was kept normal at all times; we simply increased the oil, and that is the only change in the operation that we made.

Q. 77. With reference to the statement you have just made, the figures you gave are from this table headed "Ray Consolidated Copper Company, comparative results obtained from air machines and retreating machine when consuming more than one per cent of oil per ton and also one half of one per cent of oil per ton, using the same mixture throughout." That is the table you refer to?

A. Yes.

Q. 78. Now, as to the results obtained on your table, there is a tabulation of the results obtained by eliminating fuel oil from the oil mixture; what was the purpose of that operation, eliminating the fuel oil?

A. I simply eliminated the fuel oil from the oil mixture to see whether we could maintain results. We tried at different times to run on straight fuel oil, but we could never maintain metallurgical results; so we eliminated the fuel oil and used the same out of Barrett No. 4—approximately the same amount that we

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used in the mixture of both, and on April 7th on our retreating plant feed using straight Barrett No. 4 on 344 tons, consuming 2.39 pounds of Barrett No. 4, we made a tailing of 1.083, with an indicated extraction of 85.95. On April 8th, on the retreating plant feed using straight Barrett No. 4, treating 356 tons, consuming 1.31 pounds of oil, which corresponds to the amount of Barrett used when we consumed 11.27 pounds of mixture, we got a tailing of 1.25 with an indicated extraction of 82.89 per cent. Now, on April 7th the extraction through these figures represents a decrease of 10 to 14 per cent by eliminating the fuel oil. On April 7th while treating slime vanner tailings using straight Barrett No. 4, treating 245 tons, consuming 2.07 pounds of Barrett No. 4, we made a tailing of .456, an indicated extraction of 33.65. On April 8th, treating the slime vanner tailings, treating 273 tons, consuming 1.13 pounds of straight Barrett No. 4, we maintained a tailing of .543, or an indicated extraction of 25.39.

Q. 79. Those last two operations, on the 7th and 8th of April, compare with what other amounts?

A. Well, they don't compare with the results on March 30th or 31st and April 1st when we used large quantities of oil, because on those days we used straight coal tar. I then simply ran the straight Barrett on our slime feed to see if it was possible to maintain our percentage of extraction with straight Barrett. We found that it fell practically 15. per cent below.

MR. SCOTT: I offer in evidence the tabulation

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referred to by the witness, quoted "Comparative results obtained by air machines and retreating machines, etc."

Tabulation admitted in evidence without objection and marked DEFENDANT'S EXHIBIT No. 154. (Two sheets).

Q. 80. Do you have any difficulty in getting the necessary oil for these flotation operations?

A. We have very little difficulty in getting the oil necessary for one per cent of oil in our feed on our retreating machine, but we have very great difficulty in getting enough of the oil that we use on our slime treatment; it has practically been to date impossible to get enough oil to continue operations daily with the use of more than twenty pounds of oil per ton on 7000 tons of feed.

Q. 81. You have described all of the machines in the plant, have you not, the air machines and the pyramid for the slimes and the other machines for the vanner concentrate?

A. The mechanical machine—we have another small machine there that we are treating a hundred tons per day with, using 20 pounds of oil to the ton, simply for experiment. It is called the K. K. machine.

Q. 822. What kind of a machine is that?

A. Well, it is a single unit within itself. I don't know hardly how to describe it. It is a rotary with baffles on a shaft enclosed in a sort of cylindrical housing. The feed goes into one end with the oil, and this

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rotary revolves approximately 180 revolutions a minute and it simply churns the feed and the oil and the air that it takes in at the intake, against the housing, and discharges it through round holes into a long spitzkasten, which is the length of the machine, and from this the concentrate is removed from the tailings and discharged at the opposite end of the machine from where it comes in. I have some cuts here of the machine, I have a drawing, but there is no flow sheet of this machine because it goes in at one end and out at the other, and the concentrates go out of the spitzkasten.

Q. 83. Those cuts that you have got, do they make its construction clear at all?

A. Well, not unless you really understand the machine. Here is the cut I have. I also have here a photograph of the machine in operation.

MR. SCOTT: We offer the photograph in evidence.

Photograph admitted in evidence and marked  
DEFENDANT'S EXHIBIT No. 155.

WHEREUPON an adjournment was taken until 2:00 P. M. Saturday, April 28th, 1917.

Q. 84. This morning I asked you to compare in amounts of copper that would be recovered, by the figures prior to January, 1917 and afterwards, more than 20 lbs. of oil was being used. Will you state whether that figure that you gave, 17 lbs. of copper, expresses any real facts regarding the comparative merits of the two operations and if not how you would compare them.

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A. Well, in figuring the pounds of copper saved by extraction it does not mean anything to mill operation. We figure pounds of copper saved and the advantage or disadvantage of the process, in the amount of copper going to waste in the tailings per ton of ore. And, in comparing the year <sup>of</sup> 1916 with the year ~~of~~ 1917, the way we would compare it, on the pounds of copper going to waste in the tailings, you really must find the tonnage or the relative amount of tailings in comparison to the tons of ore treated, and I find on figuring by ratios of concentration, getting the tons of concentrate produced per ton of ore treated, and then getting the ton of tailings made per ton of ore treated. Taking your tonnage of tailings times your assay of your tailings, I find that when using for the year 1916, 3.36 lbs. of oil per ton we have practically the same amount of copper going to waste in our tailings as we had during the year 1917 when we were operating with 20.1 lbs. of ore per ton.

Q. 85. Referring to the tabulation of the treatment of the slime vanner tailings, state whether or not the operations, the daily operations from February 8th to 28th were regular and constant or not.

A. Well, our daily operations on slime feed is practically normal at all times. That is, each hour of the day is practically the same as the preceding and the succeeding hours. We have immense storage facilities. The capacity of our plant consists of Dorr thickener, then we get our feed to the vanner and then to

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the flotation, is handled in such an immense quantity that there is, each hour during the day, they won't vary to any extent in feed. Now, during the period that you mentioned, the period from February 8th to 28th, when using 20 lbs. of oil or more in our slime feed, we treated on the 8th, starting out the operation, a very much smaller tonnage than the rest of the month would indicate. On this day we treated 180 tons. Then, for the succeeding days we averaged between 367, 336 and 378 tons per day, showing that our average was practically uniform, every day, every hour for every day in that month; and our oil consumed will average between 19.84 to 21.85 lbs. per ton for each day, showing that the average is practically normal at all times.

Q. 86. Now referring again to this tabulation of slime vanner tailings treatment, you say that the tonnage down to the end of 1916 is apparently greater than that after you began to use a large amount of oil. Now will you state why that is so?

A. In our slime treatment we found that we got best results when using crude coal tar and our tonnage was so great in this machine or on this product that we have been unable to date to secure a sufficient amount of coal tar to run our entire plant and so we just simply get enough oil to run at the times that we can, and we are endeavoring to collect as much of that coal tar as we can, and at the present time we have practically 100,000 gallons of coal tar which will throw the entire installation on a 1% or more of oil. In

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order to operate daily on our tonnage with 1% or more we would have to have approximately 14,000 gallons of coal tar a day or we would average about 140,000 lbs. or better than 3,000,000 lbs. per month. We have been unable, to date, to secure more than 50,000 gallons per month, so that we have to collect this oil and store it until we get enough to run five or six or possibly ten days on 1% or more. We have endeavored to get the coal tar from any source possible.

CROSS EXAMINATION,

BY MR. WILLIAMS:

X-Q. 87. What did you do in this slime vanner plant on the days between those that are given in 1917 in your table, exhibit 151?

A. We operated with our usual amount of oil, as we operated previously to this year.

X-Q. 88. That is you say the smaller—that is to say you used the smaller amounts of oil that you used before, in the days between when you have not got a large amount to use?

A. Yes.

X-Q. 89. And you have not made any showing of those operations in your table?

A. No. I have not indicated that for the year 1917.

X-Q. 90. You have described a pyramid plant, or a set of machines arranged in pyramid, a set of air

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machines, and represented them in a separate drawing. I suppose they are separate plants, are they?

A. They are separate plants.

X-Q. 91. In none of these proceedings which you report here were they run together, is that right?

A. Yes they are arranged so they can be run together or run separately.

X-Q. 92. Did you ever run them together?

A. We did.

X-Q. 93. Do any operations appear in the reports where they were operated together?

A. The operations of January 17th and 18th, the operations of March 15th to 17th, and of March 20th to 26th.

X-Q. 94. Have you described the manner in which they were connected up; possibly I have not followed you when you testified?

A. I have in this note below here, where I say that we recleaned twice; it simply means that we operated the pyramid as a roughing machine, and then recleaned by the air machine, which gives us a double recleaning.

X-Q. 95. Now, when you use the air machines alone, what was the condition of the feed to the plant? You have noted here feed, and you have noted oils as going into the same place. Had there been any preliminary mixing of the ore and the oil?

A. There had not.

X-Q. 96. So that in this instance you used this

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long series of air machines to perform the operation of mixing as well as aeration, is that right?

A. Well, I will correct that statement to this effect. We did for a while send our feed and oil through the same emulsifier and then we sent our feed separately, and only our oil and water through this emulsifier, and the two combined just as they entered the machine.

X-Q. 97. So that in that instance you had a pre-emulsification of the oil?

A. Yes.

X-Q. 98. But it was pre-emulsified out of contact with the ore?

A. Yes.

X-Q. 99. Did you maintain that as a standard operation?

A. Well, not during the entire. We would switch from one to the other.

X-Q. 100. There were times when there was no pre-emulsification of the oils, and without any pre-mixing or emulsification of the ore and oils you fed ~~the~~ ~~and~~ oils separately and the ore separately into the air machine, is that right?

A. There were times when we did both.

X-Q. 101. In the operation with smaller quantities of oil did you ever use the air machine alone?

A. You are speaking of the slime vanner tailings, are you?

X-Q. 102. I understood that it was part of the slime plant?

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A. It is.

X-Q. 103. Yes. If you ever used it in any way, just tell me; tell me what you know and then I will know what you know.

X-Q. 104. Yes. You mean when we treated the slime vanner tailings in the air machine with small quantities of oil?

X-Q. 105. Yes.

A. We did.

X-Q. 106. In what manner was the oil and ore fed as to emulsification?

A. The ore and oil were emulsified before entering the machine.

X-Q. 107. Emulsified together?

A. Yes.

X-Q. 108. Can you tell me when you commenced to use this air machine?

A. I don't know whether I have the date on that or not. It was in the latter part of 1916. The result I have here showing the result of the air machine on small quantities of oil is of January 10th, 1917.

X-Q. 109. That is the first entry that you have?

A. As a roughing machine, no; we used it in the latter part of 1916 as part of our cleaning system of our entire installation; I don't know just what date we put it in, but it was in the latter part of the year 1916 that we put it in.

X-Q. 110. Did you put it in in the last month, in December?

A. Yes, I think it was in December.

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X-Q. 111. I notice in your table "Flotation Operations treating slime vanner heading and slime vanner tailings," that the first period given is the second quarter of 1915, with the smaller tonnage than any succeeding quarter. That was the commencement of the operation of this plant?

A. Yes.

X-Q. 112. And as the plant was then installed at the commencement of operation, in what respect did it differ from the plant that you have described?

A. At the commencement of operations the plant was a straight mechanical machine.

X-Q. 113. Janney?

A. Yes. We did not have the pyramid installation then; it was five mechanical cells followed by five mechanical cells arranged in multiple. There was a feed going to each cell separately from the others, and the tailings combining and going to five cells separately. There were two lines of machines, five in each, in multiple, a straight mechanical machine. Then later on we installed the air basket.

X-Q. 114. You had in this first plant your first set of machines and roughers, and your second set of machine cleaners?

P. 3265, L. 27, insert "roughers, and then followed by another set of five as" after "as".

~~were arranged in multiple~~

X-Q. 115. What did you do then with the middlings from the cleaner machines?

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A. They circulated back to the head of the roughers.

X-Q. 116. Give me the date for some one day's operations in that first quarter of 1915?

(Witness produces book.)

X-Q. 117. Now, let us take June 15, 1915, please read off to me your record for that day, taking the numbers with the head of the column so that the number will be understandable.

A. 631 tons of heading, 549 tons of tailing, 15 tons of concentrate, 951 lbs. of No. 4 oil, 21 lbs. of pine oil; total 972 lbs. of oil.

X-Q. 118. And what was No. 4 oil?

A. That is the Barrett's No. 4 creosote.

X-Q. 119. Now, you might give me the average for the month of June or the smallest period that you have operated upon the amount of oil used per ton of ore treated.

A. Well, I will give you the average for the month of June, 1.91 lbs. of oil for the month of June, 1915.

X-Q. 120. Now let us turn to July, 1915. Were the oils used the same during July as during June or was there a change?

A. There was a partial change. I find that we used during the month of July some California fuel oil.

X-Q. 121. In addition?

A. To Barrett's No. 4 and the pine oil.

X-Q. 122. Now, read off the descriptive entries for July 15, 1915.

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A. Treated 1121 tons; 1081 tons tailings and 40 tons of concentrates; 1468 lbs. of No. 4 oil; 41 lbs. of pine oil; total 1509 lbs. of oil.

X-Q. 123. Have you the assay of the heads, concentrates and tails of that day?

A. I have.

X-Q. 124. Read them.

A. Headings, 1.13%.

X-Q. 125. Copper?

A. Copper. 81.13% insoluble, 2.05% iron; tailings .535% copper; concentrates 17.3% copper; 31.33% insoluble; 10.9% iron.

X-Q. 126. Now will you give me the similar assay for that day, June 15, 1915?

A. Heading 1.4% copper; 84.73% insoluble; 2.7% iron; .473% copper tailings; concentrates, 26.53% copper; 29.87% insoluble; 10.27% iron.

X-Q. 127. Now, give me the average per ton of ore in the month of July, in this plant, 1915.

A. 2.01.

X-Q. 128. Now, let us turn to the beginning of 1916. In January of 1916 had there been any change in the oil used?

A. I will have to look and see. In January, 1916, we were using Lewis tar acid and Jones oil.

X-Q. 129. What is Lewis tar acid?

A. It is a creosote, coal tar creosote with, if I am not mistaken—This was a 30% tar acid content in the creosote.

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X-Q. 130. And the Jones oil, is there any other name for that?

A. I have never heard it. It has the appearance of a crude oil.

X-Q. 131. And these were the only two oils used during the month of January, 1916?

A. They were.

X-Q. 132. Now, let us take the 15th of January, 1916, read off the record for that day.

A. 2261 tons treated in the head; 2226 tons tailings, 25 tons of concentrates; 2470 lbs. of Lewis tar acid; 823 lbs. Jones oil; 3293 total lbs.; 1.45 lbs. of oil per ton of material treated.

X-Q. 133. Now, let us have the assays of that day.

A. .75% copper in heading; 91.80% insoluble, 1.6% iron; .506% copper in the tailings; 22.96% copper in concentrate; 24.93% insoluble in concentrate and 8% iron in concentrate.

X-Q. 134. Now, I would like a typical individual day in among these operations during the present year

P. 3268, L. 24, insert "Take the run of February 8th to 28 in this same plant" after "ton"

of concentrates, 7560 lbs. of coal tar, 20 lbs. of oil per ton of ore.

X-Q. 135. That is very close, isn't it?

A. Some here go below and some above.

X-Q. 136. Now, we will have the assay.

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A. .710% copper in headings, .393% copper in tailings; 13.06% copper in concentrates; 63.06% insoluble in the concentrates; 6.03% iron in concentrates.

X-Q. 137. Now, we will take the record for February 11, 1917.

A. Treated, 463 tons headings; 456 tons tailings, 7 tons of concentrates; 85.68 lbs. of coal tar, 18.50 lbs. per ton of material treated.

X-Q. 138. Now the assay.

A. .680% copper in headings; .455% copper in tailings; 14.46% copper in concentrates; 50.20% insoluble; 7.20% iron.

X-Q. 139. Before I leave this particular plant, what did you do with the material, what did you do with the kind and grade of material that you treated in this plant before you installed it?

A. This material was treated on our big permanent installation.

X-Q. 140. Of what kind of concentration?

A. Flotation concentration.

X-Q. 141. No; before you had flotation.

A. This material was going to waste.

X-Q. 142. Not, in the other plant, for retreating the vanner concentrate products; is that right?

A. Yes, sir. This statement is wrong. We shipped this product to smelter.

X-Q. 143. Your fourth quarter—Your table shows the fourth quarter of 1914 as the first entry. Will you let me have a daily record during that fourth quarter? Take the record of November 15, 1914.

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A. Treated, 207 tons of heading; 163 tons of tailings; 44 tons of concentrates; 624 lbs. of creosote, 212 lbs. of California fuel oil.

X-Q. 144. And the total pounds of oil per ton of ore is then given for the day?

A. Yes, sir. 836 lbs. of total oil; used 4.34 lbs. of oil per ton of material treated.

X-Q. 145. Now, the assays.

A. 7.23% copper in the heading; 73.80% insoluble; 7.13% iron; .563% copper in tailings; 4% iron in tailings; 31.87% copper in concentrates; 22.53% insoluble in concentrates; 16.93% iron in concentrates.

X-Q. 146. Now, let us go to the first quarter of 1916 in that plant. Give me the figures for January 15th, 1916.

A. 250 tons heading, 201 tons tailing, 49 tons of concentrate, 487 lbs. of Lewis tar acid, 161 lbs. Jones oil, 40 lbs. Chesapeake pine, total 689 lbs. of oil; 2.76 lbs. of oil per ton.

X-Q. 147. What is Chesapeake pine; pine oil or pine tar?

A. Pine oil.

X-Q. 148. Now, the assay.

A. 5.4% copper in headings; 73.6% insoluble; 6.9% iron; .40% copper in tailings; 26.1% copper in concentrates; 60.9% insoluble; 21.2% iron.

X-Q. 149. Now, let us look at some of the operations in 1917 with larger quantities of oil. Were these operations continuous from their commencement?

A. Yes, sir.

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X-Q. 150. Give me the record for January 8th, 1917.

A. Treated, 300 tons headings, 240 tons tailings, 60 tons concentrates, 5432 lbs. California fuel oil; 603 lbs. Barrett No. 4 creosote; total 6035 lbs. of oil, or 20.11 lbs. of oil per ton.

X-Q. 151. Now, the assays?

A. 5.3 per cent copper in heading, 77.4 per cent insoluble, 6.2 per cent iron. 4.96 per cent copper in tailings, 24.50 per cent copper in concentrate, 28.3 soluble in concentration~~ton~~ and 18.16 per cent iron.

X-Q. 152. Now give me the record for January 9th, 1917?

A. Treated 300 tons; 238 tons tailings, 62 tons concentrate; 5342 pounds of California fuel oil, 297 pounds pine oil, 297 pounds Barrett No. 4; total oil 5936 or 19.78 pounds of oil to the ton of material treated.

X-Q. 153. Now, the assays?

A. 5.7 copper in the heading, 76% insoluble, 6.2 per cent iron. .583 per cent copper in the tailings, 25.2 per cent copper in the concentrate, 29.23 per cent insoluble, 17.13 per cent iron.

X-Q. 154. Now, let me look at the report for February, 1917. Give me the report of February 24th, 1917?

A. 300 tons of heading, 204 tons of tailing, 96 tons concentrate. 4471 pounds California fuel oil, 497 pounds Barrett No. 4, total 4968 pounds of oil, or 16.56 pounds of oil per ton.

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X-Q. 155. Now, the assays?

A. 8 per cent copper in the heading, 71 per cent insoluble, 8.2 per cent iron. .380 per cent copper in the tailing, 24.26 per cent copper in the concentrate, 27.36 insoluble, 19.2 per cent iron.

X-Q. 156. In these figures that you have given me of the assays, has there been an inclusion of a copper oxide?

A. Yes.

X-Q. 157. In the tailings?

A. Yes.

X-Q. 158. And did your tables show the amount of oxide, or was that separately assayed.

A. The assay indicated in the table takes into account the amount of oxide in the product.

X-Q. 159. Does it include it or exclude it?

A. The assay includes the oxide.

X-Q. 160. So that the tailing is actually composed of so much metallic copper and so much oxidized copper, and they are both counted together in the assay?

A. Yes.

X-Q. 161. How large a factor would that be in the operations, the amount of oxidized copper that goes in the tailings?

A. Well, it is greater than fifty per cent of the copper in the tailings; for instance, if you have four tenths of one per cent copper in the tailings, .28 will be in the form of oxide and .12 in the form of sulphide.

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X-Q. 162. And that is a fairly uniform average is it?

A. Yes.

X-Q. 163. My attention is called to the fact that I said metallic copper when I should have said copper sulphide. You understood me to mean copper sulphide?

✓ A. Yes, that was just a mistake.

X-Q. 164. Now, in your operations have you used anything else than oil, ore and water?

A. That is, any other chemicals?

X-Q. 165. Yes.

A. We have not?

X-Q. 166. Or acid?

A. No acid.

X-Q. 167. And no other reagent?

A. The only thing that is in the ore is, they add lime at the mine, simply to protect their screens and rolls at the head of the mill, but that is not done for any flotation purpose, because we can get very much better results without the lime than with the lime.

X-Q. 168. That is, the ore as it is dug out of the ground is a little acid?

A. Yes.

X-Q. 169. You put in lime to neutralize that?

A. Yes.

X-Q. 170. And is that true of your operations since the first of the year as well as before?

A. Well, we ran into the acid ore about the middle of 1916, about the middle of the year, and it has been continuous ever since.

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X-Q. 171. The acid?

A. Yes.

X-Q. 172. That is sulphuric acid of course?

A. Yes.

X-Q. 173. Do you ever heat your pulps?

A. No, sir; we have never tried heat.

X-Q. 174. Now, I wish you would describe for the court what an operator does when he is controlling the operations of a flotation plant? Let us go back to the time when you used the small amount of oil. Of course you understand just how it is done, and I would like you to tell what the operator does, what is it that controls him in his regulation of the plant?

A. He pays very close attention to the amount of oil he is adding. He can tell by the appearance of his machine whether he is adding a sufficient amount of oil to maintain good results.

X-Q. 175. By the appearance of the froth in the machine?

A. By the appearance of the froth in the machine and the way the machine is acting. He inspects his elevators every so often, to be sure that there is no slippage and that the feed is coming to the plant steadily, and tries to maintain normal operating conditions at all times. He will go over his machine and determine whether he has sufficient air to produce a concentrate whereby on the recleaner he will maintain the grade that we would like to have maintained in our plant, and any irregularities that happen in

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the plant, why he is so trained that he knows exactly what to do and where to go in order to counterbalance this fluctuation of operation.

X-Q. 176. I suppose the appearance of the froth is one of the important indications when anything needs attention, is it not?

A. The appearance of the froth, as well as the discharge of the froth.

X-Q. 177. That is the amount?

A. The amount.

X-Q. 178. The amount of the overflow?

A. Yes.

X-Q. 179. In these machines of yours do you have a natural overflow or do you help it along with a paddle?

A. No, in these machines we have no mechanical froth removers at all.

X-Q. 180. The froth just overflows by gravity?

A. Yes, in this slime treatment. In treating the concentrate we have mechanical removers. The froth is much heavier and more compact, but we don't have the mechanical removers on the series cells of the cleaning machine. We have at the multiple machines where we make the finished concentrate, but the slime treatment we have no mechanical removers.

X-Q. 181. What are the conditions in the appearance of the plant by which the operators are told to reduce the oil supply?

A. In operating, if the appearance of the froth is

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sort of—our slime is yellow slime, and if the appearance of the froth is too yellow, he comes to the conclusion that he is discharging more insoluble or a lower grade of froth than he really should, and you can either cut down or diminish the air to a certain extent, or you can cut down your oil, and when the operation is normal or practically so, you can maintain about the same results at that point. Cut down your agitation or cut down your oil.

X-Q. 182. Can you give me separately the oxides and the sulphide copper assays of the heads and tails for the year 1916?

A. I think I can.

X-Q. 183. Will you do that?

A. Yes, sir. I cannot give you the heads; I can give you the tailings. On treating slimes, the per cent of oxidized copper in the tailings will average for the year 1916 .20. On retreating the concentrate, the oxidized copper in the tailing for the year 1916 will average .18.

X-Q. 184. Now, have you got it for the first quarter of the year 1917?

A. I can give it to you by the month.

X-Q. 185. All right, give it for each month separately.

A. For the month of January, 1917, the percentage of oxidized copper in the slime tailing was .276, and for January, 1917, the percentage oxidized copper in the tailings for retreating concentrate was .214. For the month of February, 1917, percent oxidized copper

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in the heads for February, 1917, on our slimes was .311; percentage of oxidized copper in tails for slimes during month of February was .266; percentage oxidized copper in concentrates, retreating concentrates, was .19.

X-Q. 186. Now, these figures in the slimes plant have been both the operations with amounts of ore exceeding 20 lbs. and operations with amounts of oil less than 20 lbs. per ton of ore, have they not?

A. Yes. This statement is made up of the total slimes treated regardless of the amount of oil used.

X-Q. 187. Now, what arrangement does your company have for the selling of concentrates?

A. We have a flat rate with the smelter. If I am not mistaken, it is \$5.00 per ton of concentrates regardless of per cent. of copper, insoluble or iron; we are not penalized for insoluble and we are not penalized for iron.

X-Q. 188. And where are your concentrates smelted?

A. In the town of Hayden, about a quarter of a mile from the concentrator.

X-Q. 189. What is the name of the smelter?

A. It is the American Smelting & Refining Company.

X-Q. 190. Now, in regard to your contract, isn't that affected by the price of copper?

A. No, I think not. We have a flat rate of so much per ton of concentrate.

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X-Q. 191. Do you know that as a fact, or is it just a matter of information?

A. No, I don't know that as a fact. I haven't seen the contract, but that is my understanding.

MR. WILLIAMS: We have still of course to have the operations such as have occurred since the first of the year connected up with the prior art, and with that reservation for the completion of that testimony, I close the cross examination at the present time.

#### RE-DIRECT EXAMINATION

BY MR. SCOTT:

R-Q. 192. What is that \$5.00 you mention; is that a smelting charge?

A. That is a smelting charge per ton of concentrate, that they charged the Ray Consolidated Copper Company.

R-Q. 193. How about the amount of attention and adjustment the flotation apparatus requires when, say 20 lbs. or more of oil are being used per ton as compared with when using three or four pounds?

A. They make no change in the operation at all.

R-Q. 194. I meant the amount of attention it requires from the attendant.

A. It requires no more attention to operate with 21 pounds than it does to operate with three-quarters of a pound.

R-Q. 195. I think you found a cut of that K & K machine this noon?

A. Yes, sir, I have a cut of the machine.

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R-Q. 196. I wish you would briefly explain the operation of that machine and put any letters on you need to, to tell what these two pictures are you have.

A. "A" will represent the intake for feed and oil. "B" represents tailings to waste. "C" represents concentrates discharged. "D" represents the shaft on which this baffle spindle is connected which revolves at the rate of 180 revolutions per minute. "E" will represent automatic operating float discharge. "F" will represent housing surrounding the rotator which is composed of baffles.

R-Q. 197. Can you explain the operation better from the cross section?

A. On the cross section view "A" will represent the rotator which is built up of baffles. The feed comes into the machine at one end and the centrifugal force of this rotary, which is 180 r.p.m., draws the feed and the oil and discharges it against the inside of this housing.

R-Q. 198. Where is the pulp in the machine before it is picked up by the rotary?

A. Well, it comes right in at one end of the rotary. The rotary is entirely the machine.

R-Q. 199. Just make a mark to show where this pulp is thrown.

A. The pulp would hit in right by the letter "B".

R-Q. 200. Now, place a letter where the pulp is picked up by that rotary.

A. The pulp is picked up at the letter "C".

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R-Q. 201. And then it is whirled around in this upright space between the rotary and the housing?

A. Yes, sir.

R-Q. 202. Then put a letter where it is discharged.

A. Discharged at letter "D".

R-Q. 203. Where does the air come from that makes the bubbles for the froth?

A. The air comes—goes in with the feed at the intake and also at the end, with the shaft, supported by the bearings. The air goes in at both places. There is suction on both ends of the machine and suction at the intake of the machine; three places where the air can enter the machine.

R-Q. 204. Are these placed apart, these what you call baffles, or slats, whatever they are?

A. Yes, about a quarter of an inch apart.

R-Q. 205. Do I understand that the air is drawn out through there, and this narrow sheet of pulp?

A. No, you understand the air is taken in at the ends and entered into the machine at the same point that the feed enters, and this inside of this rotary, there is chance for the feed to get inside of there, too, through these places where the bearing is.

R-Q. 206. You said the pulp progressed through the machine; what is its movement, its course?

A. It would progress similar to a curve.

R-Q. 207. You mean it goes around through the rotary more than once?

A. In starting the machine without any oil at all, and putting your oil in, the froth will first form at the

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head, and then it will work slowly down to the tailings.

R-Q. 208. MR. WILLIAMS: You have this rotating device as a long cylinder extending the length of the machine and rotating at the speed you have stated? Is that right?

A. Yes, sir.

R-Q. 209. This cylinder has an outer surface composed of what you call baffles which appear to be supported by slats; is that right?

A. Yes.

R-Q. 210. Now, outside of these baffles there seem to be some similar contrivances; what are they?

A. Those are baffles.

R-Q. 211. Those are real baffles?

A. Those are real baffles. This is just the timber to attach the baffles to.

R-Q. 212. So that these baffles are practically a series of slats extending over the outside of this rotating cylinder?

A. Similar to the riffles on a Wilfley Table.

R-Q. 213. And what is the over-all length of the machine, about?

A. It is 14 feet long and about 4 feet high.

R-Q. 214. And about what is the diameter of that rotating cylinder inside?

A. As close as I can estimate it is about two feet: probably a little larger.

R-Q. 215. No, if it is four feet high, if the machine is four feet high—

A. (Interrupting) 32 inches they have there, to be

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exact. It is 32 inches—that of course takes in the base and the housing.

R-Q. 216. The over-all height of the machine is given here as 32 inches. It can be readily computed.

A. I don't know what the exact dimensions are, but that housing is only about an inch and a half timbers.

R-Q. 217. The inside of the housing is smooth?

Yes, sir.

R-Q. 218. And it is a complete water tight housing?

A. Yes, sir.

X-Q. 219. I don't remember just what you said about the use of this machine. Is it—what is it used now in your plant for?

A. We are using that machine to test different kinds of oils now, and we did use it as a test on some small quantity of oil, and with large quantity of oil, just a comparative test of the two.

R-Q. 220. And you found it worked pretty well with either?

A. Equally as good with the large percentage of oil as it does with the small percentage.

MR. SCOTT: I offer this illustration, one of them on the large sheet entitled "K & K Flotation Machine" the other the small folder entitled "K & K Flotation Machine Bulletin No. 1".

The documents were admitted in evidence and marked DEFENDANT'S EXHIBITS 156 and 157.

(WITNESS EXCUSED.)

Ben H. Dosenbach.

BEN H. DOSENBACH, recalled for further direct examination by Mr. Scott having been previously sworn testified as follows:

DIRECT EXAMINATION,

BY MR. SCOTT:

Q. 1. You are familiar, are you, with the Everson patent?

A. I am.

Q. 2. Have you ever attempted to carry out the process described therein?

A. I have.

Q. 3. What apparatus have you used for carrying out this process described in the Everson patent?

A. One form of apparatus that I have used is an apparatus that is built according to the Fryer Hill publication.

Q. 4. That publication that is in evidence?

A. That publication that is in evidence in this case.

Q. 5. Have you the machine here?

A. I have.

Q. 6. Will you refer to the Fryer Hill publication and compare the description therein contained with the machine itself?

A. With reference to the Fryer Hill publication, the "Daily Herald Democrat," Leadville, October 30th, 1889. This is a publication which refers to a certain method of concentrating ores with the use of oil,

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and in that description a machine or apparatus is described. This publication states that "The whole system of concentration appears to be based on the well known affinity of the lighter forms of sulphuret and chloride of silver for oils. Petroleum is the oil now being used by the parties having these experiments in charge and appears, from its density, to possess the requisite adhesiveness to effect the results desired." It says that "The ore is first crushed and rolled to such a degree of fineness as to enable it to pass through a 40 mesh screen and while dry, is thoroughly mixed with the oil, after which it is placed in a circular tank or receiver."

Q. 7. What are you reading, Mr. Dosenbach; the Fryer Hill publication?

A. Yes.

Q. 8. Unless you have some comment to make on some part of it it won't be necessary to read it.

A. Well, I was just coming to the description of the machine in this publication and I will follow it up by referring to the machine itself, which I have now in court and also to a drawing which represents the machine. The ore is thoroughly mixed with the oil "after which it is placed in a circular tank or receiver." This is the circular tank or receiver that will be used in the experiment which is illustrated in this drawing by the circular tank or receiver.

MR. WILLIAMS: I just want to call attention to the fact that the witness said "The ore is thorough-

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ly mixed with oil" omitting two lines of the description, one part of which says that the ore is crushed so as to pass through a 40 mesh screen.

THE WITNESS: I have read, that, Mr. Williams, begging your pardon.

MR. SCOTT: If you wish to, you can point out on the machine as you read it.

A. "Through the center of which runs a rotating hollow tube," which is this rotating hollow tube in the drawing and this rotating hollow tube on the machine itself. "To the bottom of which tube is attached, on two opposite sides, a couple of fans," which are these fans at the bottom of the hollow rotating tube as shown in the picture, these two rotating fans,— "the lower edges of which are unevenly cut in order to send—in the revolutions—the lighter particles of the ore and oil mixture to the outer sides of the drum or cylinder." That is ~~this~~<sup>the</sup> lower edges of the fans which are unevenly cut, so as to give an upward motion to the agitated material, which is shown on the machine itself, are unevenly cut, the lower edges of the fan. "This rotating hollow tube is perforated at, or near, the bottom," which shows several small perforations at or near the bottom, just small holes, just above the fans. "and, when the receiver is thoroughly charged, acidulated (sulphuric acid is used). Steam is introduced through the tube and is forced to the bottom of the mixture while the arrastralike fans, attached to the bottom of the tube, keep the whole mixture in

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motion, and, the action of the revolving tube, the fan, and injected acidulated steam causes the lighter portions of the mineral-charged oil to float to a point just above the center of the receiver, where there are suspended two semi-circular doors, when the oil has passed above them, laden with its precious freight, are raised, and the superfluous water allowed to drain through slight perforations in the bottom of these semi-circular doors, after which the mineral-laden oil is carefully removed to settling barrels revolving with jets of steam injected continuously from the lower end." Well, the rest of that we needn't show, because that is an after treatment to recover the metal. These doors, however, are perforated, as shown in the machine itself, and also in the drawing which I have here. This shows the shaft and the semi-circular doors raised, and this shows them when they are lowered after agitation. The mineral froth rises to the surface above the doors and the doors are closed, and as the description says, "in order to recover the metal."

Q. 9. Now, will you state what ore you are going to use and how you are going to proceed in carrying out the experiment or demonstration.

A. In the experiment that I am about to perform according to the Everson patent and also the Fryer Hill publication, I will use Utah Copper ore, or the retreatment classifier overflow from the Utah Copper Plant.

Q. 10. What quantity of oil are you going to use?

A. I will use 300 gms. of this ore and to it I will

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add 51 gms. of a petroleum distillate. After adding the 51 gms. of petroleum distillate I will thoroughly mix the dry ore and the oil, making a homogeneous mass of the oil and ore. This will then be placed into the receiver of the machine, and I will then add 1250 c.c. of water. The machine will then be started, and as I cannot use any steam or acidulated steam, I will use hot water containing sulphuric acid, to correspond to the acidulated steam which is mentioned in the Fryer Hill publication. The agitation will be continued for possibly two or three minutes. I will perform the experiment, and after having performed the experiment, will give a complete description of the operation.

(Whereupon a short recess was taken.)

(Test No. 30.)

THE WITNESS: Now, if you would like to have a sample of that ore that we are going to use in the experiment, you can have it.

MR. WILLIAMS: Very well, we will take it.

Q. 11. You might state, while we are waiting, whether or not you are going to use the forty mesh material described in the Fryer Hill publication?

A. I am going to use material that is through a forty mesh screen, yes, sir.

Q. 12. You are metallurgist enough to know that what you have said may have several meanings. Is this forty mesh?

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A. It will all pass a forty mesh. There will be approximately two or three per cent of it on a sixty-five mesh, which is slightly finer than a forty mesh screen, and ranging from there on up to the finest size, which is minus 280 mesh.

Q. 13. That is to say this is a product containing a great amount of slime?

A. It is a product which contains about 60% minus 200 I should say. As I remember—and I will refer to the publication—the publication states the ore is first crushed and rolled to such a degree of fineness as to enable it to pass through a forty mesh screen.

Q. 14. THE COURT: Well, are you ready for this experiment?

A. Yes, sir. They have been sampling the ore, so as to give the other side half of the same material that I am going to use, and that has consumed considerable time.

I will now add oil, 51 gms., to the dry ore, and thoroughly mix the oil and the ore until a homogenous mass of oil and ore is formed.

Q. 15. THE COURT: You have what weight of oil and ore there?

A. I have 51 gms. of oil to 300 gms. of ore, which makes 17 per cent of oil relative to ore.

Q. 16. MR. SCOTT: Where do you get that proportion of oil to ore; what is it based on?

A. That is taken from the Everson patent, the figures as used in the Everson patent being reduced to the proportions that I now use. The oil and ore

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is now thoroughly mixed. I will now add 1250 c.c. of water, having a temperature of 42° C. I have now added 2.4 c.c. of sulphuric acid to 50 cubic centimeters of hot water, which I will add after starting the machine. (Machine started.)

Q. 17. MR. WILLIAMS: At what speed is that arrastra revolving?

A. I don't know what you mean by arrastra?

Q. 18. Well, the agitator that you have there, how fast does that revolve?

A. I will tell you in just a minute; I have it marked so I can tell when the machine stops.

(Machine stopped.)

Q. 19. MR. SCOTT: How would you describe that float as to its structure and what it is made up of?

A. I would describe that float to be a mineral froth consisting of copper sulphide mineral, air bubbles, which can be seen very distinctly by observing from the top, and naturally there is present around those air bubbles some oil. That froth I take to be something over an inch thick; about an inch and a quarter in places, and an inch in places, or an average of about an inch and an eighth. The differentiation from the tailings is a very noticeable difference, showing that there has been quite a concentration.

Q. 20. Will you compare this operation which you have just performed with the course of proceeding in actual concentration in a mill?

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A. It is very similar to the actual procedure in a mill, with the exception that in a mill there are a number of these same operations carried on in series, whereby the tailings resulting from this one particular operation would be retreated in another vessel of the same character as this one. There may be a great number of them, anywhere from 5 to 14, or possibly more or less, and this constitutes a part of the operation.

Q. 21. The first step, as it were?

A. The first step I should say. The tailing is settling very rapidly now, showing comparatively clear water between the tailings at the bottom of the solution or the vessel and the froth upon the surface.

Q. 22. In actual operation is it customary to make a final tailing with one operation of this kind?

A. It is not. They continue the operation and recover additional froth and mineral in a froth from the tailing that we now see in the bottom of the cylinder.

Q. 23. Is there any way in which you can get a sample of that concentrate there for analysis?

A. Why, yes, I can get a sample of the concentrate for analysis, showing the degree of concentration, that is, the amount of valuable mineral that is contained in the froth as compared to the original ore with which I started.

Q. 24. In that particular apparatus is there any way of getting all of that froth off, so you could determine the total amount of mineral that is in it?

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A. There is no possible way of recovering all of the froth in this apparatus, as the apparatus itself is merely to show the purpose that it was built for, and not for metallurgical recoveries; but a sample of the froth can be obtained and analyzed to show the extent of the concentration.

Q. 25. Will you do that now?

A. I can do that, or I can have it done and go ahead.

Q. 26. Well, it might save time if you have some one ~~froth~~ <sup>from</sup> each side do that?

A. That would simplify matters to have a representative from the other side assist one of the men from this side, and mutually agree as to the sample of the concentrate.

Q. 27. MR. WILLIAMS: Those doors which acted as baffles in that agitating operation, what use are you going to make of them now?

A. I will spread the doors out, as stated in the publication, and recover as much of the concentrate as possible, so that analysis can be made of the product, and I will do that myself so that it can be seen just how they work. Now, I have closed the doors, as it were.

Q. 28. MR. SCOTT: Raised them to a horizontal position.

A. Raised them to a horizontal position.

Q. 29. And they are down here below the froth as the court can see; they were hanging vertical, and you have opened them out?

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A. Yes. Now, the jar will be lowered, and the concentrate froth will rest upon the doors.

Q. 30. Instead of raising the doors in this machine, you simply lower the jar?

A. Yes.

Q. 31. MR. WILLIAMS: You did not give me the speed yet at which it turned?

A. Yes, I will give you that speed. It was between 1400 and 1500 revolutions per minute. Now, if one of the representatives from the other side is present and can assist in the operation we might go ahead, or watch the procedure.

Q. 32. MR. SCOTT: I would like the court to see how you get that off; it will only take a minute. You might state how efficient that method of getting that froth is?

A. It is a very inefficient and crude method of recovering the froth, but it shows the nature of it.

Q. 33. Where is the jar; you cannot get it all?

A. No, I cannot possibly recover all of it.

A. Now, I would like to state further that it can be readily seen that when lowering the jar and recovering the metal upon the cylindrical doors, that some of the mineral has fallen down to the bottom of the vessel and rests down in the tailings. There is quite a noticeable difference between the mineral which has fallen and the gangue material which are at the bottom, the mineral being very dark in color, lying in a stratum above the tailings; the tailings being very much

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lighter in color than the original ore, and decidedly so, as compared to the mineral in the froth.

Q. 34. Was there any dark mineral on top of the tailings, in the bottom, before you performed your operation with the doors?

A. There was not, and that was my reason for wishing to show it at this time.

Q. 35. Now, the other day Dr. Sadtler testified regarding the cataract machine described and illustrated in a German book which he produced. Have you had a machine made in accordance with that description?

A. I have.

Q. 36. Have you the machine here?

A. I have and I will bring it forth. If you will pardon me, I would like to state definitely what I used in that experiment, so that it may be upon the record. In the experiment that I have just completed, following the Everson process in the Fryer Hill machine I used 300 grams of Utah Copper retreatment classifier overflow containing approximately 7.9% copper, 5.36% iron and 77% insoluble. To this ore I added 51 grams of a petroleum distillate and thoroughly mixed the two until a homogenous mass was formed. This oiled ore was placed into the cylinder of the machine and 1250 c.c. of water added at a temperature of 40° C.; the machine was then started up and 2.4 c.c. of sulphuric acid and 50 c.c. of hot water was added and the agitation continued for a period of 2½ minutes. Upon stopping agitation a mineral froth formed above

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the semi-circular doors, being about 1 1/8 inches in thickness. After allowing the gangue material or tailings to settle to the bottom of the cylinder so that the solution was comparatively clear between the froth and the gangue I opened the semi-circular doors so as to spread them out horizontally and then lowered the cylinder, leaving a portion of the mineral froth resting upon these doors. The mineral froth that remained on the doors was then removed from the doors and the contents will be reported later.

Q. 37. I hand you the book that Dr. Sadtler referred to by Louis Andres and ask you if that is the illustration following which you had the machine constructed.

A. This is the illustration from which the machine that I will now present has been constructed.

Q. 38. Did you read it or have someone translate the descriptive part of the book for you?

A. Dr. Sadtler has translated the descriptive part of this book. It is in German and I am not very good at that.

Q. 39. Will you produce the machine?

(Witness produces the machine.)

MR. SCOTT: I might state for the information of the court that this publication following which that machine was built has been referred to by witnesses as describing an operation under the Everson patent and this is how we followed that. Now, this apparatus which Mr. Dosenbach has now was built after this

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publication, which was some years before the date of the Everson patent, the purpose merely being to use an apparatus that was known at that time.

MR. WILLIAMS: And this apparatus was an oil purifier, oil purifying machine, so described, was it not?

MR. SCOTT: If you want to testify you may do so, or have me.

MR. WILLIAMS: Well, if your honor please, I object to wasting the time of the court by carrying on experiments in an oil purifying machine for the purpose of showing an operation of ore concentration; as wholly incompetent, irrelevant and immaterial.

THE COURT: What is the purpose of this?

MR. SCOTT: The Everson patent described the agitation, the thorough agitation of the mass, and this agitator is simply taken from the technical literature.

THE COURT: You simply want to show that there were appliances that would agitate?

MR. SCOTT: And by performing this operation that would bring about the type of agitation suitable for the purpose of the patented process.

THE COURT: There is no question at all that at that time the world was full of agitating apparatus; every farmer's kitchen and yard had them, as far as that goes.

MR. SCOTT: The point was very strenuously made in the other trials that the record showed no agitating apparatus that was capable of accomplish-

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ing the purpose, and great stress was made of it in the argument. I thought myself it was rather a far fetched point; and, being made and advanced seriously why we considered that we must meet it.

THE COURT: Well, how many more like it have you?

MR. SCOTT: Well, we will illustrate the Kirby patent.

THE COURT: No, I mean of these appliances that you want to show that were capable of agitation?

MR. SCOTT: This is the only one.

THE COURT: Let the record show what it is and the objection will be overruled. I believe the doctor already testified that this was an oil purifying machine.

MR. SCOTT: Yes, it is in the book; that is in the record and it has been referred to as an agitation apparatus. I think that is the point they laid emphasis upon.

Q. 40. Now, Mr. Dosenbach, have you found it possible to carry the Everson procedure on this apparatus?

A. I have found it possible to carry out the Everson procedure in the apparatus as set forth in that book described by Dr. Sadtler.

Q. 41. This is the same apparatus regarding which Dr. Sadtler's remarks appear on page 740?

A. It is the same apparatus as testified to by Dr. Sadtler.

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Q. 42. That built under your direction?

A. This was built under my direction.

Q. 43. And in proportion and form does it conform to the description in the German book you referred to?

A. It does with the exception that I had this glass cylinder put on here so as to see the result and the froth, and the proportions are very similar. There are baffles as stated—as shown in this illustration which are also in the machine and can be noted. This is a cross section and the baffles run around the whole circumference, inside directly above these two fans or arms which are shown in the bottom of the illustration. Directly above the baffles and on the shaft is shown another—a disk, which is this—I am pointing out now, and I take it from the illustration that the disk revolves with the shaft.

Q. 44. Now, will you state about what ore and the proportion you are going to use in illustrating the Everson process on this cataract apparatus?

A. I will use a material that is very similar to the one that I used in illustrating the previous Everson experiment. It is a Utah copper ore or a material called Utah copper retreatment classifier overflow.

Q. 45. That is what the other was?

A. That is what the other was. It is similar material.

Q. 46. Now, if you will proceed?

(Witness performed experiment No. 31.)

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A. I now have thoroughly mixed the ore and the oil.

Q. 47. How does the froth which you have formed in this cataract machine compare with the one which you made in the Fryer Hill machine?

A. They appear very similar in character. The froth formed in this machine is highly mineralized, consisting of copper sulphide, mineral and air bubbles. They seem to be very much the same in richness. However, the froth is a little thicker, it appears to be so, in this experiment as compared to the previous experiment in the Fryer Hill publication.

Q. 48. Was there more mineral in this or the other one?

A. There possibly might be. The amounts are very close.

Q. 49. What was the assay of the material used in the Fryer Hill machine?

A. An assay of the material treated in the Fryer Hill machine was 7.9 per cent copper, and in this machine I have it to be 6.18 per cent copper. There was a little more iron in the ore that I used in this experiment than in the one that I used in the previous experiment. The iron in the ore as used in this experiment was 6.69 per cent as against 5.36 per cent in the Fryer Hill experiment.

Q. 50. When you said this froth was thicker you meant it was of greater depth?

A. Greater volume and height.

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Q. 51. You didn't mean the consistency of the froth?

A. Absolutely not, because it will be readily seen the individual bubbles that are shown on the sides and also on the surface.

Q. 52. Did you give all the details of this experiment?

A. I have not given all the details but I will do so. During the process of the operation I took the speed, and it will be necessary to count this ratio before I can give it. The speed of agitation was 724 revolutions per minute.

Q. 53. And how long was it agitated?

A. Two minutes and a half. I will give the proportions as used in the experiment.

In the experiment just completed, following out the Everson patent in the so-called cataract machine I used 200 gms. of Utah copper retreatment classifier overflow, containing about 6.18 per cent copper, 6.69 per cent iron and 76.2 per cent insoluble. I added to this 200 grammes of ore, 34 gms. of Texas petroleum distillate, and thoroughly mixed the two to form a homogeneous mass. Having placed this oiled ore in the machine, I added 1250 c.c. of water at a temperature of 30° C. I next started the machine, and directly after starting the agitator I added 50 c.c. of hot water containing 1.6 c.c. of concentrated sulphuric acid. The agitation was continued for two minutes and a half at about 720 revolutions per minute. The

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result upon stopping the agitator was that a very highly mineralized froth appeared on the surface of the pulp.

Q. 54. Are you going to remove a sample of that froth resulting in this experiment?

A. I think it would be advisable to remove a sample of the forth and furnish a duplicate sample to complainants.

Q. 55. Have you the material here this afternoon to perform a demonstration illustrating the California Journal of Technology article? If not, we will put it off?

A. I haven't it down here, no.

Q. 56. Well, we will go on with something that is here.

Q. 57. THE COURT: Let the court understand —these two experiments represent the Everson process?

MR. SCOTT: The specific quantity of oil and the amount of—and the kind of the oil.

Q. 58. Now, could you this afternoon demonstrate the Kirby process with 25% of oil?

A. I can.

Q. 59. Suppose you do that, then? Describe what you are going to do, if you wish to first?

A. I would suggest that a representative of the other side here assist in removing some of the froth that appears in the cataract machine.

I will perform an experiment using 25% of kerosene distillate, which is a thin distillate hydro-carbon,

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on some of the same material—a sample of the same material that I have used in the two Everson experiments. In the experiment that I am about to perform, illustrating the Kirby patent, I will use 300 gms. of Utah copper retreatment classifier overflow, the assay of which is about 6.15 per cent copper, 6.6 iron, and 76.2 per cent insoluble. I will use 1500 c.c. of water at a temperature of about 25° C., and 2 c.c. of concentrated sulphuric acid. The oil which I will use is kerosene or petroleum distillate, and I will use 92 c.c. of this oil, which is equivalent to 75 gms. or 25 per cent of oil relative to ore.

Q. 60. MR. WILLIAMS: Where is the Kirby machine?

A. I am performing the demonstration in the agitating glass jar machine.

MR. WILLIAMS: I object to that, and call your honor's attention to the fact that the Kirby patent shows a complete and elaborate apparatus capable of reproduction, and of which we have made a reproduction, and of course you can only understand what a patentee means by doing the thing as he did it. Now, this is an attempt to repeat the operation which takes place in that complicated machine, in a square glass jar, just as it was done in the Supreme Court of the United States and in Wilmington, Delaware, by these plaintiffs, and it seems to me that it is a waste of the time of the court to repeat in a glass jar, with terrific agitation, an operation which obviously could

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not have taken place under such conditions, and that the only operation that will be in the slightest degree relevant and material to this case will be an operation carried on in the Kirby machine. I will ask your honor to look at this machine, consisting of two vessels, an agitator and a separator, with all the details shown in the drawings.

In the next drawing is shown the separator, and there are still further drawings; a carefully devised apparatus, and here we have a glass jar with a rotating stirrer.

THE COURT: Well, now, I am a little doubtful of the value of some of these experiments myself, but, circumstances, of course, will be taken into consideration by the court in weighing the evidence. For instance, now, in the last two experiments which you say illustrate the Everson process, where do you get that agitation in the Everson process?

MR. SCOTT: The Everson patent says the mixture is thoroughly agitated. Now, the patent in suit has no stronger language than that on the subject of agitation.

THE COURT: Well, we will allow it to proceed for the purpose of the record. The objection will be overruled, and, as the court said, the circumstances, of course, will be considered. Really what you will do now, you might as well say, would be the process of the patent in suit with 25% of oil, wouldn't it?

MR. SCOTT: Absolutely; that is exactly what it is. The Kirby patent recommends that quantity of oil,

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and has really stronger language on the subject of agitation than the patent in suit. A process patent, as the Kirby patent is, is merely required to illustrate some apparatus capable of carrying out the process; the process is in no way related to the apparatus. This can be done in anything, a glass jar or with an egg beater, or any apparatus. So why build a complicated structure like Kirby had when the object is simply to show that agitation will produce the result.

THE COURT: Objection overruled.

Plaintiff excepted.

(Test No. 32)

THE WITNESS: I am now adding the acid after having added the ore and the water in the glass jar. I will next add 92 c.c. of distillate.

(Machine started and run for some time)

Q. 61. What result have you in this experiment, Mr. Dosenbach?

A. A very copious, highly mineralized froth is formed.

Q. 62. Are there any more details as to that experiment, or did you say everything you wanted to before you started it?

A. I gave the quantities used, and so forth, before starting the experiment. The only thing that remains is the agitation, which was for a period of three minutes at approximately 1600 revolutions per minute.

Q. 63. Have you prepared an experiment in which you make a froth and sinking granules with the same amount of oil?

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A. Yes, but I haven't time to complete the experiment this evening as it takes ten to twelve minutes to continue the experiment alone, much less get it ready.

Q. 64. You might describe it; it won't take but a little time to describe it and use the time up, so that we will get it in the record?

A. Yes, I can do that. I have performed an experiment and can repeat the same, using the cone Gabbett—

MR. SCOTT: I would like the record to show that samples of the froth in this last experiment as well as in the others, have been furnished to representatives of the plaintiff.

THE WITNESS: (Continuing) The experiment that I am speaking of was performed in the cone Gabbett machine on Butte & Superior ore using oleic acid and in one instance I obtained a froth and by reducing the agitation, the mineral sinks, and by again increasing the agitation the mineral will again float.

Q. 65. You mean all in the same mixture, by alternately agitating differently?

A. By alternate procedures, first obtaining a froth and then sinking the mineral and then obtaining the froth again, and I presume the operation could be continued alternately in the same manner for an indefinite length of time. However, I have not tried it more than several times each. The percentage of oil was upwards of one per cent—one per cent plus relatively to the ore. I think I used one and one half per cent of oleic acid relative to the ore used and the agi-

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tation was constant for from five to ten minutes for each procedure.

Q. 66. Now, as the representatives of the plaintiff are going to visit the Butte & Superior mill tomorrow I think it would be a good idea if you take this time now and make a little sketch, flow sheet, and explain it to them. There will be time enough to do that?

A. Yes, I will get my flow sheet here.

Q. 67. You can do it on the board if you wish to?

A. Well, I can do that although I have prepared, several days ago, a large flow sheet, and you can observe any points on it just as well as looking at a diagram upon the blackboard.

Q. 68. Have you sent for it?

A. Yes, it will be here in just a moment. This flow sheet represents the flow of the material and the machines used in the flotation plant at the Butte & Superior Mining Company. It shows a plan view of the various machines that are used and there are eight in number, all identical, alike.

Q. 69. What does each one of these units show, the circle and a triangle at the end of it?

A. I may start in this way; this is one machine which we call a pyramid machine, which consists of seven cells. Each one of these agitating cells that I am pointing out here in the center has two spitzkastens, one on each side of it. There is a double row ~~of~~ spitzkastens and a single row of agitators to each primary machine. There are eight of these primary machines

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in the flotation plan that treat the same material. The material as it comes to the flotation plant and goes to this machine is practically all alike, and there is a distributor that divides it into eight equal portions. Here we have a cleaner and a recleaner machine which takes the product from the roughing machine and re-treats the concentrate for the purpose of obtaining a purer grade. Now, I may follow this way, the flow of this in a general manner, and if there are any questions I can stop and answer them as I go along. For the purpose of illustrating and not to confuse with a great number of lines on each one of these pyramid machines, as they are all alike, I have selected one of them and on it I show the various products that are made and where they go.

MR. GARRISON: What number have you selected?

A. I have selected No. 7, and it shows by the red lines where the products go. That will not confuse the other machines, and the products from the other machines, joins along with No. 7 so we can consider the whole plant, when we speak of No. 7 pyramid. The original material coming to the flotation plant, which is the tailing from the concentrating or wet separation part of the mill is indicated by the words "slime and tube mill product." That material comes from the concentrating department and goes to two 36 inch elevators, No. 1 and 2, where it is elevated to a junction box indicated by numerical three. The junction box has an under-flow and an over-flow. The under-flow goes

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to an 8-way distributor from which it is distributed to these eight pyramid machines that I have just described. The over-flow goes to what we call the sludge tank, which is just an alleviating tank to take the variation in the feed that is discharged from the elevators. The underflow from the sludge tank flows to the elevator again and is a closed circuit so the sludge tank takes care of any excess of material that may come at any one given time. Now, before being distributed to the 8 pyramid machines, the feed is sampled by an automatic sampler, designated on this flow sheet by the numerical five. After being distributed we follow down to No. 7 primary, and if it was retreated in No. 8 it would be the same for each one of them. The material enters No. 1 cell. And as I said before each primary machine is a unit in itself and consists of seven cells. These seven cells are attached in series and the feed enters the first at this point, travels from the spitzkasten here into the next one and so forth down until it reaches No. 7 and through No. 7. That is the general flow of the material through the machine. Each one of the cells has two spitzkastens, one on either side of the agitating cells, where concentrates and middlings are taken off. The first three produce a rougher concentrate where—which is Nos. 1, 2 and 3. The next four, Nos. 4, 5, 6 and 7 produce a middling, which middling goes back again to these 36 inch elevators before mentioned and to the original feed, coming back again to the machine. The rougher concentrate that is made in cells Nos. 1, 2 and 3 go to a 16 inch elevator

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where it is elevated to a small alleviating tank, No. 19, which is only a feed tank supplying material to the five cleaners which are all in pairs—have been in pairs, but are now as one machine—and as we follow the rougher concentrate it enters at this point and travels through these five machines or five cells to be washed, the same making a cleaner concentrate and a cleaner tail. Now, that cleaner tailing is no more than a middling product, the same as the concentrate recovered on the last four cells of the rougher machines and it goes back again to be retreated together with the original feed that is coming at all times, and that is a continuous operation. Now, the cleaner concentrate that is made upon this cleaner unit is elevated again to this tank 20, and goes to the recleaner where a final concentrate is made. The recleaner tailing goes to the rougher concentrate elevator and the recleaner cells where it is in a closed circuit, it being a little higher grade than the cleaner tailing. Then the tailing resulting from the No. 7 cell of the rougher machine goes to air cells of the pneumatic type, there being 14 in number. However, I have not shown the 14 as I wished to reserve this space, but there are 14 of them—where a final tailing is made from these air cells which goes to the tailings pond and to waste. The concentrate or middling product which is produced by these air cells goes back again through the system as a middling and is retreated with the original ore that enters the machine or enters the plant from the concentrating department of the mill.

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Q. 70. MR. WILLIAMS: What is the arrangement of these air cells? Are they all in series?

A. They are all in parallel.

Q. 71. All in parallel?

A. Yes.

Q. 72. So that the tailings go through—

A. (Interrupting) 14 of them.

Q. 73. 14 of them?

A. Yes, sir, in parallel.

Q. 74. One after the other?

A. Not if they are in parallel, no.

Q. 75. In parallel the tails would be divided into fourteen different lots, each going through one machine? Is that right?

A. Yes, sir.

Q. 76. That is what I supposed, but I wanted to make it clear?

A. Yes.

Q. 77. Where do you put your oil in? I suppose you use oil, a little?

A. Yes, I think we do, a little. We put the oil in before it comes to the elevator. We have put the oil in at the junction box and also the sludge tank. We are provided to put oil in at these places, but right now we are adding the oil to the feed as it comes to the flotation plant from the water concentrating department.

Q. 78. MR. GARRISON: Can you indicate on there the place where you feed the oil?

A. (Witness indicates on drawing).

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Q. 79. MR. GARRISON: How have you indicated it?

A. By putting a circle and "oil feed" on there.

Q. 80. Have you any copies of this drawing?

A. I haven't any copies of this particular drawing but I will endeavor to furnish copies for tomorrow, a number of them, so that your representatives will be as familiar as they would be if they had this one.

WHEREUPON an adjournment was taken until Monday, April 30th, 1917, 10:00 A. M.

10 o'clock A. M. April 30, 1917.

MR. GARRISON: If your honor please, two weeks ago yesterday we served upon defendants a notice to produce various papers, and in response thereto, after producing some papers, they stated that they would be unable to definitely respond to the balance of the notice until they had had further opportunity to make search, with which your honor concurred, very properly. It has now been two weeks that they have had this opportunity, and I desire to renew the call, particularly with respect to the vouchers, checks or other evidences of payment of moneys by the defendant corporation to James M. Hyde.

MR. KREMER: If there is anything of the sort found we will produce it.

THE COURT: Are you able to answer now?

MR. KREMER: I can not answer now because I have not paid any particular attention to the inquiry, outside of my first inquiry. I will ascertain at the noon hour if they have found anything. If they have, they will be glad to produce it.

MR. GARRISON: The suggestion was that they had to communicate with New York, and they have had time to do that.

MR. KREMER: If we have found anything we will produce it. I don't know whether they have got anything from New York or not. I have not inquired since the first day.

THE COURT: Are you ready to proceed this morning?

*Renyon*  
MR. KREMER: If your honor please, we noticed a motion in this case, for leave to file an amended and supplemental bill. I don't know whether there will be any objection to it.

MR. KREMER: Yes. We desire to object to the filing of the proffered supplemental and amended bill for the reason that said supplemental bill is not a supplemental bill within the contemplation of law or the process of this court, in that it sets forth only the matters which were known to the complainant and plaintiff during practically the entire pendency of this suit. For the further reason that no proper or sufficient or any showing has been made which would justify the filing of the supplemental or amended bill. The paper proffered is accompanied by a notice that the complainant <sup>and</sup> will, on April 30th, move the court for leave to file a so-called supplemental and amended bill.

of complaint, a copy of which is attached to the notice. There is no other showing made to the court. We object for the further reason that the so-called paper or document is conjunctive, in this, that it purports to be a supplemental, as well as a amended bill, and no showing is made to the court, by petition or otherwise, which would justify the filing of the bill as drafted. For the further reason that the bill, upon its face, discloses the fact that under the law governing the filing of supplemental pleadings, and particularly supplemental bills, and under the decisions of the courts regulating the filing of the same, this supplemental bill is improper for the reason that it sets forth only matters which were disclosed, by the very nature of the allegations, to have been known to the complainant at all times during the pendency of this suit, and the application for leave to file the supplemental bill is not timely and was not made until this case had proceeded a number of days, although at all times the complainants, according to their own allegations, were advised of the conditions therein contained. That is shown by their own allegations and the allegations in the prior pleadings in this case.

For the further reason that the attitude of the complainant in now applying to file this supplemental bill is not one of equity, in that they came into this court and proceeded to introduce their testimony and concluded their case, plaintiff holding itself out as the owner of this patent and entitled to proceed with this lawsuit, with a view to obtaining such benefits as it might obtain through the lawsuit, withholding

from the defendant all of the information now contained in this supplemental bill, and no application was made or notice given to file a supplemental bill until after the defendant had placed upon the stand Mr. John Ballott, whose testimony disclosed that it was known to them at all times, the fact that this plaintiff was not the real party in the case.

We further object for the reason that in order to file a supplemental bill it must be apparent that the application is made timely and that the matters and things set forth in the supplemental bill are of such a character that they develop during the pendency of the suit and were acted upon with expedition and with diligence when they were disclosed. And it further appears that by the exercise of due and reasonable diligence facts, or alleged facts, set forth in the supplemental bill should have been presented to this court long before the time of their application.

We further object to the filing, if I might segregate it—I don't know how I can when the paper is labeled one and the same thing. A conjunctive appellation of supplemental and amended bills—but referring to that portion of the bill that sets forth what is purported to be amendment to and in substitution of paragraph 8 of the bill of complaint, the defendant objects to the alleged amendment for the reason that it is not timely; for the reason that all of the contentions therein contained were objected to by the defendant herein at the time of the attempted introduction of proof and a ruling was made that the complaint was broad enough to admit the character of testimony to which the objection

was directed. That being so, it is not timely now to propose this amendment, and particularly is the amendment not to be allowed for the reason of the long delay and lack of diligence in filing the same, and for the further reason that the said amendment, under its very allegation, is not sufficient in law, and by reason of this fact it is apparent it should not be permitted to be filed in view of the fact that no showing accompanied it and it is contrary to the decisions of the Supreme Court of the United States involving a like matter of law.

We submit the motion. Has your honor looked—I don't know as it is just fair to submit it. I think I should advise the court.

THE COURT: I certainly should know what is brought into the case or attempted to be brought into the case by this new bill.

MR. KREMER: If your honor please, by this supplemental bill, first, as I have stated in the objection, there has been no showing made to this court. My understanding of the practice is a showing must be made to the court for leave to file a supplemental bill; there must be something affirmative before the court, and there is nothing before the court, not a mere paper to which is attached a notice. I think upon that question of practice we all have an understanding of what is necessary. I don't know that all that is necessary is to present a paper. I think you must make a showing to the court, your reasons for desiring to file the supplemental bill. Now, I understand the further fact—I wish you gentlemen would correct me if I misstate this, because I am not quite as familiar as you are with it.

MR. KENYON: We will be glad to do so.

MR. KREMER: I think I can state it from the allegations. The supplemental bill alleges that the plaintiff, Minerals Separation Limited, entered into a contract or agreement of American rights, using the term broadly, of this patent on the 10th day of October, 1910, when there was granted to the Minerals Separation American Syndicate, Limited, the plaintiff herein, certain rights under said patent for a term of years. These rights were renewed by a written instrument from time to time up to 1916. Now, although it is shown to have been known that the Minerals Separation American Syndicate, had certain rights, they were not made parties plaintiff to this suit. We had no information, that is the defendant. And later it is alleged—

MR. KENYON: You want me to correct you if you have made a misstatement of the facts?

THE COURT: You better let them take that and they can present their side of the motion.

MR. KREMER: All right, I would be very glad to have them state it.

THE COURT: You have completed your objection, Mr. Kremer?

MR. KREMER: Yes, I have completed my objection.

THE COURT: Let them proceed with their motion.

MR. KENYON: The objects of the amended and supplemental bills are several. I will take them up in order. First, it is decreed the mandate of the Su-

preme Court in the Hyde case, the disclaimer that followed in consequence and the final decree that was entered in the Hyde case. Attached to this supplemental bill of complaint is a full copy of the mandate, with its date; of the disclaimer with its date; and of this final decree with its date, these documents showing that these various things occurred and they are proper matters for supplemental bill, not under the ordinary and accepted practice, but under the very rules of this court itself, where in rule 24, under "Supplemental Proceedings" it is stated: "Upon application of either party the court or judge may, upon reasonable notice and such terms as are just, permit him to file and serve a supplemental proceeding, alleging material facts occurring after his former pleading." Under this branch of it, this branch of our supplemental bills comes in.

Another branch of the supplemental pleading is what our motion and bill substantially amounts to, a plea to intervene by Minerals Separation, North American corporation, to acquire title on December 7th, 1916, such title as the Minerals Separation, North American corporation, acquired on December 7th, 1916. This supplemental traces back to its origin along in 1913. Giving the original document of July—some day in July, 1913, when Minerals Separation, Limited, one of the plaintiffs and Minerals Separation, American Syndicate, 1913, an intervening British corporation, together agreed, the one to sell and the other to purchase the beneficiary interest in the American patents, including the patent in suit, upon the happening of certain conditions and the making of certain pay-

ments. Our supplemental bill alleges that these conditions were finally perfected, and these payments were finally made in October, I believe it was, October 6th, 1916, at which time, last October, became invested in this intervening American Syndicate, the beneficial interest of these patents, legal title to which still remained in the Minerals Separation, Limited. And, as I say, on December 7th, this new corporation that now asks to be admitted as a party plaintiff, Minerals Separation, North American Corporation, <sup>ac</sup> required the entire right, title and interest of this intervening American Syndicate of 1913 in this patent for whatever that 1913 Syndicate had, and in all causes of action that had accrued to this 1913 syndicate in the interval of its ownership. Therefore, this Minerals Separation North American Corporation, that now asks to be made a party plaintiff, while not the owner of the legal title to the patent, that remains in the Minerals Separation, Limited, at the present time, is the owner of the beneficial interest in that patent, and is therefore in equity properly, and rightfully to be included as a party plaintiff; and for the purpose of the accounting that we anticipate, should be a necessary party plaintiff to the end that the defendant itself may be protected from any further litigation connected with the same acts of infringement of this patent. And that is the purpose of bringing in this new plaintiff at this time, in defendant ~~and~~ of the defendant, so that every possible interest that has any equitable right of any kind in the accounting shall be actual parties to the accounting and bound by it. On the face of the papers the proceedings occurred

as of the date October 6th last and December 7th last. It hardly appears that any additional affidavit of diligence need be filed as to the delay in the interval because no possible harm can have been occasioned the defendant by that, and this bringing in of this corporation makes the pleading now accord with the facts that were brought out for the first time in the testimony of Mr. Ballott. These are facts occurring then since the bill was filed, having to do with an equitable interest that will be concerned in the accounting and is properly brought in this form of pleading.

As to the amendatory character of the bill, it consists of two measures; first, as to the Hyde and the relations of this defendant to the defense of the Hyde suit. We strike out by this amended bill our allegation in that regard in the original bill and substitute an amended allegation, stating the facts as we now understand them, making the pleadings agree with the proof, the proof that has been brought out here in the last few days, and which we could not in the nature of things, have ~~been~~ known until we saw this correspondence and examined these witnesses. That part, therefore, of the amendment is merely to make the pleadings agree with the proof.

And, finally, there is only one branch left, and that is a residuary interest, a certain residuary equitable interest in a third and the original American Syndicate **that is called "Minerals Separation, American Syndicate, Limited,"** which is the British Corporation of 1910.

Counsel, in following back these complicated title

papers connected with these three successive American corporations, one of 1910, a British corporation, one of 1913, a British corporation, and finally this last one of 1916, an American corporation, discovered just within a few days for the first time that there was this residuary equitable interest, left hanging in the air, as it were, and never assigned to anybody, an interest that accrued—a right of action that accrued to this 1910 American syndicate, by reason of infringements occurring between October 10th, 1910, and October 10th, 1913, because as the papers show that we attached to this document, on October 10th, 1910, that first of the three American corporations became an exclusive licensee under the patent in suit, and so remained until October 10th, 1913, when its license expired by limitation, and when all other rights and interests that were vested in it, were, by the British counsel who prepared these papers, transferred to other interests and reverted to Minerals Separation, Limited. But there was omitted from that document, as it chanced, such interest as had accrued to that first American syndicate of 1910 in the recoveries that might be made against infringers who infringed during that period, that is, from October, 1910, to October 10th, 1917. That happens to leave a small part of the infringement that will have to be accounted for here, in case a final accounting is decreed, and while an exclusive licensee under the authorities can not maintain an infringement in his own name—

MR. SHERIDAN: Oh, yes, he can.

MR. KENYON: It can properly be joined with the

owner of the legal title in such an action for infringement. That is correct, isn't it?

MR. SHERIDAN: Yes.

MR. KENYON: The question of the legal title and the question of exclusive license for the period mentioned, that old syndicate of 1910 may properly be joined as party plaintiff, and that syndicate, which otherwise is now defunct, but still legally in existence, asks to be permitted to intervene here as a party plaintiff, to the end that even that interest, whatever it may be, and remote though it be, may be represented in the accounting, so that the defendant may never at any time hereafter be called upon by that ancient corporation to respond in damages for that infringement. That covers the whole substance of our amendment and supplemental bill, and seems to properly amend and supplement the pleadings, so that all interests, equitable and otherwise, that might by any possibility be concerned in that accounting shall be before the court and bound by whatever that accounting results in once and for all. If counsel for the defendant are not inclined to accept our statement—the statement of counsel I mean—that this residuary interest of many years ago was unknown to exist by the British counsel and unknown to the parties themselves and only brought to light by our investigation here recently, we will present an affidavit to that effect, or testimony in court. Now, that, it seems to me, is the only possible point on which any affidavit as to diligence would be required.

MR. KREMER: After hearing the statement of counsel I ask leave to supplement my objections by three additional objections.

Defendant further objects for the reason that under the statement of counsel, an attempt is being made to split the causes of action; for the further reason that under the statement of counsel the pleadings should not be permitted to be filed because, assuming that an accounting should be ordered—only assuming this by way of argument—it would be improper to permit this pleading to be filed, because, this being the date of the application for filing the alleged supplemental bill, under the statutes of the United States it would be impossible or improper to permit anyone, either the plaintiff or any one of the proposed plaintiffs, in the supplemental bill, to ask for an accounting for a greater period than six years, as the statute of limitation prescribes a six years' period for an accounting, and the six years would run back from today.

For the further reason, that this being an action in injunction and accounting it is improper to permit any party to intervene who has nothing more than an action at law, if an action at all, and it is an attempt to permit a party to become a party plaintiff whose right of action, if any, would be confined to an action at law, an action for damages. I am now referring particularly to the last corporation—I can't keep track of their names—I think it is the Minerals Separation North American Corporation.

Having added those objections I would like to reply briefly to counsel.

At the outset, if your honor please, it was stated that the paper submitted was offered for the purpose of pleading a disclaimer. Such a position can not be ten-

able upon the face of this record. There has been filed here a proper supplemental answer, setting forth the fact that the plaintiff in this case did not file a disclaimer. Under the rule it is unnecessary for them to reply thereto and that issue is before the court regardless of their proposed supplemental bill, the question of whether or not a disclaimer was filed. That matter is before the court under the rules of practice, and the issue is joined.

Now, insofar as the pleading of the mandate of the Supreme Court of the United States in the Hyde case is concerned, the final decision in the Hyde case is pleaded upon the face of the record heretofore existing, and it is unnecessary to plead the mandate of that court. It is not the mandate that gives the decision any force or effect, and there is no attempt in this case and has been no attempt to admit the face of the record in the Hyde case. The existence or possible existence of that mandate would not give force or effect to any action that the plaintiff could take under this supplemental bill that they could not have taken under the original complaint herein on file, and particularly under the supplemental answer filed by the defendant herein. Therefore I say that there is no reason for the statement to the effect that this bill is made necessary by reason of a necessity of pleading the disclaimer or the mandate. The matters are before the court by implication of law, and there is no reason for tendering the supplemental bill at this hour. That this is in fact a petition for intervention, I take it that it can not come before this court in the guise of a supplemental

and amended bill of complaint. There is a vast distinction between a petition for intervention and a supplemental complaint or an amended bill. Why, I say a vast distinction—one is the antithesis of the other, in this, that the petition in intervention is addressed to this court by a stranger to the proceedings, who asks leave to come in and have his cause litigated in the cause between these other parties. The supplemental bill is a proceeding, which, under the discretion of the court in proper cases, might be filed for the purpose of permitting then existing litigants to set up in the record something that has transpired subsequent to the filing of the original pleadings and the joinder of the issue. An amended complaint is a pleading directive in the nature of a curative character, to a pleading already in existence; and if this is, in fact, as counsel now states, a petition in intervention, it can not be offered to this court for filing in this guise.

Now, as to these various corporations I think that I was stating the case quite correctly. Regardless of the recontation of these various rights, of these corporations at various times, the fact remains that these matters must have been known—and I am not speaking of counsel, because I take the statement of counsel that they did not know—but it must have been known to the officers of these corporations who, as I understand it, are extremely closely allied—I am not sufficiently familiar with the organizations to make the broad statement that they are the same—but these facts must have been known to the plaintiff, and there is no showing that they were not known to the plaintiff. It is not a

question whether counsel knew; the client may have withheld information from counsel, with design—I am not saying that they did, if your honor please, but I am only illustrating that the knowledge of counsel is not necessary. The very paper that is here presented admits that these contracts were in existence.

Now, then, the equity of this situation, — What is it? Before proceeding with the amendment, I would like to digress here to discuss the matter of this so-called supplemental bill. What is the equity of the situation? Suppose, if your honor please, this case had gone on without our discovery of this condition—and I use the word discovery of this condition advisedly—without our discovery of this condition, and let us suppose that that condition does exist, that in this litigation this patent will be declared invalid. When that decree is entered, decreeing the invalidity of this patent, what would have been the position of this defendant? Would not the Minerals Separation, North American Syndicate, or Minerals Separation, North American corporation, or any one of the other shadows that have lurked in this darkness, protruded themselves into the light of day and say "No, you are not relieved, because I claim a right, and you must litigate this all over again." Now, that is the position. These facts were known to them. It is the clearest case of doing equity that I have ever known. They come into equity and ask equity, and at the same time they have withheld the real parties in interest in this litigation, and it was only when we, in opening our defense, called to the stand the president of one corporation and chairman of the board of the other, and brought into this record the fact that

there was still another party in interest. Now, that is the reason. There is a strong reason in equity that these things should not be done, and we seriously oppose the filing of this so-called supplemental bill at this time.

I don't want to needlessly take up the time of the court; I think I have stated my position as clearly as I can, but now, directing my remarks to the amendment or the portion of the bill designated as an amendment to the original bill: In the original bill they complain in paragraph 8—In that paragraph everything is set up, if your honor please, that is set up in paragraph 8, except the recontation, or at least an attempted narration of the plaintiff's interpretation of certain evidence in this case, which they have made in this proposed amendment. In paragraph 8, I objected to the introduction of testimony under it, as your honor will remember, and argument was had, and my objection was overruled.

(Counsel read paragraph 8.)

In paragraph 8 in the amended bill, all that they have attempted to do, and I believe counsel will agree with me in this statement, is to give their interpretation of the evidence. They may not subscribe to my interpolation of the word "interpretation" either, but it is their view of the evidence that is attempted to be set forth in this so-called amended bill, and it is improper because it is a pleading of their interpretation of the evidence. There is no reason on earth why this amendment should be filed. The issue, I submit, is raised by their paragraph 8 in this case, because your honor has ruled that

it is properly in this case. Now, that being the state of the record, it is a useless thing and an improper thing to permit an amendment which sets forth merely an interpretation by the plaintiff of the evidence in this case, and we believe that, if your honor will examine the two paragraphs, that you will conclude that it is nothing more than—

THE COURT: In spite of the ruling which was made, they may think it wise to throw out an anchor to windward. There may be an appellate court.

MR. KREMER: There is no reason, and there is no rule of pleading to permit the introduction into a pleading of an interpretation of the evidence. If it does state a condition which will permit them to have redress if they have been aggrieved, that is sufficient in law. They have set forth here an interpretation of the evidence. Now, I desire, to add this, before concluding; that in addition, after they have set forth their interpretation of the evidence, they say that to that extent—that is to say, to the extent of the letters patent in suit, 835120, may vary as to claims 1, 2, 3, 5, 6, 7 and 12 and I included by the acts and operations that are complained of, that this defendant is estopped. You see? Leaving out of the matter of their attempted plea of estoppel, claims 9, 10 and 11. I think I have correctly stated that.

MR. GARRISON: Those are the ones that are left out?

THE COURT: The new one excluded 9, 10 and 11.

MR. KREMER: Yes, sir, the new one excludes 9, 10 and 11. I think I should state this to the court, be-

cause that is the legal effect of this amendment, aside from the fact that this interpretation of the evidence is here incorporated. I am not going to read it, but I have read the short paragraph which sets forth not what entitles them to redress but merely the so-called evidence or their interpretation of the evidence which they claim to have been introduced in this case. Now, I can not see the necessity of such an amendment, if under the original pleading all of the claims are included; this would serve no good purpose by way of relinquishment, because the law would relinquish them, and we submit that this supplemental bill is an improper document to be filed at this time, and that it is improper to combine the various elements there which are sought to be combined in this pleading, and there is no sufficient showing that the bill should be filed.

MR. KENYON: May I state just a word on one or two of these points? On the second day of the trial we gave defendant's counsel informal notice that we would prepare a supplemental bill, and there was some discussion connected with it, and this <sup>is</sup> the outgrowth of that.

MR. KREMER: Mr. Kenyon, I very much dislike to interrupt counsel, but may I ask you the question to avoid the necessity of rising again? Wasn't that notice given after Mr. Ballot had testified?

MR. KENYON: I think it was.

MR. WILLIAMS: Yes, a few minutes afterwards, and I think that we should also say that counsel considered the matter on the train coming out here, and decided to file a supplemental bill as soon as they could study the numerous documents and reach a conclusion

as to what was necessary to give to the defendant that protection which would arise from including all the parties who had any action against the defendant.

MR. KENYON: And we had to telegraph to the east to get some of these documents. Now, counsel speaks of a six year limit under the law. That is true. An infringement that occurred prior to six years before the filing of the bill of complaint is barred by the statute of limitations. Therefore, as to this 1910 corporation, there is no doubt that it could not prosecute an infringement occurring six years prior to the time, whenever this supplemental bill is filed. But that is a question of the extent of the infringement, a question to be properly brought before the master, and not a question to be determinative of whether that party could sue or not within the six years. It so happens here that it already appears in evidence in this case that the defendant's operations did not begin until the first of July, 1911, so it is merely a moot question here.

Now, as to the question of these two new parties here splitting actions, and that an exclusive licensee has an action only at law. In the second proposition, counsel is correct. When it sues alone it can sue only at law for damages that have been done to it, but nothing is commoner in the administration of patent law, and the books are full of illustrations of the proposition that an exclusive licensee, although alone he can sue only at law for damages, may be joined with the owner of the legal title in a suit in equity for that same infringement, and when so joined can participate in the prayer for injunction and in the accounting for the profits, as well as for damages.

Therefore, this that we propose is not a splitting up of actions, but just the reverse, a consolidation of actions. It is a non-splitting of actions; it is a consolidation of all of them into one action whereby with one proceeding and one accounting every right and every obligation of these defendants, and of all these plaintiffs shall once for all be determined. Defendant's counsel illustrates: Suppose we had kept these equitable interests in the dark, and had proceeded in the name of the owner of the legal title only and had in the end invited the catastrophe of a decree declaring the patent invalid that then we might have brought suit in the name of one of these exclusive licensees and sued all over again. We are quite anxious to save him from that possible disaster. We are—we ask that the exclusive licensee be joined here so that it will be bound by that decision and never again be able to raise its voice. That relieves him and protects him. This court, under its own rule 19, has the broadest discretion in the matter. "The court may at any time, in furtherance of justice, upon such terms as may be just, permit any document, proceeding, pleading or records to be amended or material supplemental matters to be set forth in an amended or supplemental proceeding. The court at any stage in the proceeding will disregard any error defect in the proceeding which does not affect the substantial rights of the parties." Now, our opponent says it is not necessary to plead the decree in the Hyde case.

MR. KREMER: No, not the decree.

MR. KENYON: The disclaimer?

MR. KREMER: No, the mandate:

MR. KENYON: Then it will do no harm to plead the mandate. Pleading the decree explains the decree; pleading the disclaimer and the interval between the two explains at all times the disclaimer and the final decree; and that a disclaimer can properly be treated is also permissible and is often done. In *Fellows v. Borden*, 205 Fed. 901, the Circuit Court of Appeals, Second Circuit, allowed the plaintiff to ask the district court to file a supplemental bill after a disclaimer, in order to set up the disclaimer, and the District Court allowed it and it was filed and the case was reheard on the merits and went to the Circuit Court of Appeals on the merits of the treating so amended. And as to the Hyde amendment, some of the allegations of our bill were incorrect. We wish them amended in accordance with the evidence. In some respects they were incomplete and we wish that incompleteness supplemented in accordance with the evidence, and made complete and the residuary right of this old 1910 corporation extended not only to counsel but to the parties themselves. They were ignorant of it until within a few days when we discovered this matter in conning over these numerous documents that were admitted in evidence; they were ignorant that anything had been left, any property had been left in that 1910 corporation. The purpose had been to absolutely denude it of every possibility, of every right of every kind. But this right of action and any interest in a right of action against infringers had during this period ~~had~~ apparently been a thing unknown to British counsel and had not been included in any of the general language.

We will, if your honor please, file an affidavit that the parties themselves were ignorant until within the last week or so, of the fact that there was any right of *any* kind with reference to this infringement left in the old 1910 corporation, if your honor wishes such an affidavit on file.

MR. KREMER: I don't think that that would excuse them at all. The fact that they did not know that which they should have known is not any excuse. It is purely a question of law and legal right and we can apply the basic maxim *ignora legis nemine excusat*. They cannot take advantage of a condition of that sort by saying that they did not know or they supposed the record had been left in that condition. They could have come in here and sued for it, and alleged recovery. I do not care to take up the time of the court, but

P. 3331, L. 18, insert "concerned the only excuse offered for this amendment is" after "is"

~~TO THE MORE NEARLY THE STATE OF FACTS.~~ ——————  
ficient excuse. As a matter of fact, neither the complaint nor the amended complaint states the facts or any portions of the facts as disclosed by this present record before the court. The unimpeached record before the court at this particular time, in this case, is that Mr. Hyde had sold his rights, and that the Butte & Superior had purchased them for an expenditure equal to the amount of the cost of the litigation. There was no evidence of the control of the litigation or anything of that sort. Now, we submit the matter.

THE COURT: Does this supplemental bill purport to take the place of the original bill or simply an addition to it?

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MR. KENYON: An addition to it only in respect to one paragraph, paragraph 8 does amend it.

THE COURT: Well, the main feature seems to bring in these parties who have a right to share in the fruits, if there are any, for the plaintiff. There is an old maxim that courts of equity delight to do complete justice and not by halves. I will take the two pleadings and look them over and dispose of them in the morning. You may proceed with the case.

BEN. H. DOSENBACH resumed the stand for further

DIRECT EXAMINATION.

Q. 81. Mr. Dosenbach, have you ever investigated the possibility of concentrating by flotation and a froth with the same amount of oil that is recognized for this Cattermole process in which the mineral is sunk?

A. I have.

Q. 82. How have you proceeded with this investigation?

A. I have performed an experiment in what is called the cone Gabbett, using a proportion of oil to ore that is over one per cent and which is very close to the proportion recognized in the Cattermole patent, that being 4 to 6 per cent relative to the metalliferous mineral content. The amount of oil relative to ore that I propose to use and that I have used is one and one-half per cent, which reduced to proportions compared to the metallif-

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erous mineral content is about seven per cent. In the experiment I performed I used oleic acid and Butte & Superior ore.

Q. 83. Suppose you just describe the procedure before you do it so that we will know what to look for?

A. In the experiment that I am about to perform in the cone Gabbett machine, using a proportion of oil that is over one per cent and also a proportion of oil recommended in the Cattermole patent, I will use 300 gms. of Butte & Superior ore containing about 14.8 per cent zinc. I will add to that 1500 c.c. of water at a temperature of 35° C. I will use also 1 c.c. of sulphuric acid concentrated and 5 c.c. of oleic acid, which is equal to 4.5 gms. or one and one-half per cent relative to ore. The agitation will be continued for possibly six minutes, at a speed of 1600 to 1700 revolutions per minute.

Q. 84. And what will the result be of that first agitation?

A. The result will be a froth.

Q. 85. And then what do you propose to do after you have obtained that froth?

A. I will reduce the agitation and it will be noted that the mineral sinks. And, by again increasing the agitation it will be noted that there is a froth formed.

Q. 86. A second froth?

A. A second froth.

Q. 87. And who will—and how will you conclude the demonstration?

A. I will conclude the demonstration by reducing

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the agitation again, sinking the mineral and separating the mineral in an upcast, as is done and recommended in the Cattermole patent.

Q. 88. And all of these operations will be conducted in the very same mixture?

A. They will.

Q. 89. Now, as I remember the Cattermole patent refers to the quantity of mineral, the metalliferous content of the ore. That expression does not mean the mineral itself, zinc?

A. Refers the oil to the metalliferous mineral.

Q. 90. What is the metalliferous mineral in zinc ore?

A. The sulphide of the metal.

Q. 91. You gave its contents 14.8 zinc. Is that metallic zinc?

A. Metallic zinc.

Q. 92. And how much of a per cent of blend in which that zinc is contained that is taken into account, the weight of the sulphur contained with the zinc?

A. 21.75 per cent metalliferous mineral or zinc sulphide would be equivalent to 14.8 per cent zinc.

Q. 93. Now the oil is one and one-half per cent of the weight of the ore and the ore contains approximately one-fifth metalliferous mineral, that is a little over twenty per cent?

A. Yes.

Q. 94. So that you arrive at the relation of the oil to the metalliferous mineral by multiplying that one and one-half per cent by approximately five?

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A. Yes. In actual figures it is less than five so that the amount of oil relative to the metalliferous mineral present or the zinc sulphide amounts to 7.0—something which is just a little above seven per cent.

Q. 95. Now I think you may proceed with the experiment?

A. If a representative of the other side is here we will give them a sample of the oil we are going to use.

(Performing Test #33.)

I have now placed into the cone Gabbett machine 300 gms. Butte & Superior ore. I will now add 1500 c.c. of water at a temperature of 35° C.

MR. WILLIAMS: I would like to give notice to Mr. Scott of a request for a little specimen of each of these froths that is to be made. I think one-tenth of a gramme of each will be satisfactory to us if that will not interfere with the operation.

THE WITNESS: It will be a pleasure to give it to you. After having added 1500 c.c. of water I will add 1 c.c. of concentrated sulphuric acid and will also add 5 c.c. of oleic acid and will start agitation.

Q. 96. MR. SCOTT: Now, Mr. Dosenbach, just state what the result of that experiment has been.

A. After stopping agitation, having agitated the mixture for a period of six minutes, a highly mineralized froth appears on the surface and the tailings are now settling and are very clear—appear to be very clean, and are comparatively light in color, settling very rapidly. The mineral froth that was formed is about one and one-eighth inches in thickness.

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Q. 97. Now, Mr. Dosenbach, you are next going to remove the baffles?

MR. SCOTT: I would like to have your honor see the process that goes on when he removes the baffles.

Q. 98. Mr. Dosenbach, will it interfere with you at all if you would agitate it with the baffles in before you do it?

A. No.

MR. SCOTT: He will give it the same agitation he did to make the froth, for a few seconds, and then he will change the agitation for the next step. That is the way he made the froth, with the small baffles in.

Q. 99. Now, go ahead with the next step so the court can see the difference in the way of agitating it.

A. It has a sort of a honey-comb structure on top, pitted.

Q. 100. What do these pits come from?

A. The release of certain air that allowed these pits to form.

Q. 101. What have you just done with the belts?

A. I have changed belts so as to get a lower speed. This rheostat and motor would not allow for a slow speed.

Q. 102. The speed before was about 1700 revolutions per minute?

A. No, I took the speed to be 1450 while it was operating.

Q. 103. Now it will be what?

A. About 300.

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Q. 104. You are going to leave the baffles in?

A. Yes, I am going to leave the baffles in.

Q. 105. How long are you going to agitate it this time?

A. It usually takes five to ten minutes to take the air out of there, out of the pulp.

MR. SCOTT: Let the record show that the agitation was stopped in five minutes.

Q. 106. And then what happens, Mr. Dosenbach?

A. The mineral sank to the bottom; there was no semblance of a froth present on the surface.

Q. 107. MR. WILLIAMS: Just a few little particles here and there?

A. Just a few little particles here and there, possibly ten or twelve.

Q. 108. MR. SCOTT: Now, what do you propose to do next?

A. I will increase the agitation as agitated before and the result will be a froth or I hope it will be.

Q. 109. And after that you propose to form the granules again and separate them in the up-cast?

A. Separate them in the upcast. You can see that the mineral has sunk to the very bottom.

Q. 110. Just show the court the upcast before we go any further.

A. The upcast is a sort of a classifying arrangement whereby these heavy mineral particles that have now settled in the Gabbett—

Q. 111. Coming in here?

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A. They will be emptied into the classifier or upcast.

Q. 112. And what is this tube leading into the bottom?

A. That is water that is fed from the tank up above, which supplies a flow sufficient to cause the hydraulic action in the upcast.

Q. 113. The water will come up through the glass tube?

A. It will and carry with it the light gangue material you see now in the machine.

Q. 114. And what will become of the granules?

A. The granules will sink to the bottom and be caught in the bottom, which is this part of the upcast.

Q. 115. And these granules will be the same material out of which these froths have been formed?

A. Absolutely. I have again agitated the mixture for one minute at the same speed as before, being about 1450 revolutions per minute.

Q. 116. When you say "as before" you mean as when you formed the froth before?

A. When I formed the froth before, at 1500 revolutions per minute, and the result was a froth of the very same character as obtained before.

Q. 117. You might simply continue with the last step?

A. You notice along the side of the froth the clear portion on the particles of the froth which are

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evidently air bubbles, and it shows the clear portion where the froth sticks to the side of the glass.

Q. 118. What do you mean by the clear portion?

A. That is quite distinct, here is one and there is one.

Q. 119. You mean the black spots?

A. Yes, where there is no mineral present. Would you like a sample of that?

MR. WILLIAMS: We might. We might get some information out of it. Let us have it.

Q. 120. MR. SCOTT: You ran this the same five minutes you did before?

A. No, it takes longer.

Q. 121. Why should it take longer?

A. It takes longer to form the granules than it does to form the froth because in working with a Cattermole machine, the cone Gabbett, it carries in quite an extensive amount of air through the cone and naturally during the process of agitation there will be a considerable amount of air taken in.

Q. 122. Referring to the fast agitation, or either of them?

A. Either one of them, for a short period. And it is in order to displace the air that is taken in after the first agitation that the slow rolling of the second period of agitation is necessary to be continued for a considerable length of time.

Q. 123. To get all the air out?

A. To get all the air out.

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Q. 124. MR. WILLIAMS: That is, that your present operation is one to get rid of the air?

A. Yes.

Q. 125. The machine introduces air at the same time?

A. Yes, it is very efficient for introducing air.

Q. 126. MR. SCOTT: How does the amount of air introduced when it is going slowly compare with the amount introduced when it is running rapidly, as you did when you were making the froth?

A. Very much less when it is slowly revolving as compared to when it is rapidly revolving and the froth is formed. I have agitated for a second period of five minutes and the result has been that there is no froth present. All the mineral has sunk to the bottom of the vessel. I will now proceed to separate the sunken mineral by the upcast classifier arrangement. The heavy particles are sinking and the gangue particles are going up. This (indicating) showing of the distinct mineral particles being heavier, and the slime gangue particles being the lighter here (indicating), are carried over by the up-current of water.

Q. 127. Have you got a stirrer so you can stir up those tailings so the court can see them?

A. I can catch some in my hand. I will allow them to settle a few minutes, and when the slimes have settled so there is an appreciable amount at the bottom, they can be noticed. There are a few floating particles of mineral in the upper part of the upcast

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at the time that I am draining it. You can now see the mineral and granules that have been separated in the upcast; they all occupy the lower portion of the upcast, or the bottle.

Q. 128. Does that look like a clean separation?

A. Yes, a decidedly clean separation, especially so in the apparatus that I used, being a small apparatus.

Q. 129. Are you going to sample it?

A. Yes, I would be very glad to sample it and give the other side an equal portion of the sample. I will allow the tailings from the overflow of the upcast to settle, so you can notice its condition, being deprived of the mineral.

Q. 130. I don't think you described the other portion of the operation in the upcast. I think you had better give a description of that, of the upcast and the bottle and the launder and just how you operated.

A. The upcast consists of a vertical cylinder about two inches in diameter and about 30 inches high, to which at the lower end is attached a bottle, and through which hydraulic water is introduced, causing an up-current through the vertical cylinder.

Q. 131. That was clear water?

A. Clear water which acted as an upcast, so that when the total material from the Gabbett machine was introduced into the top of the cylinder or upcast, the uprising current of water carried the lighter portions of the mixture, which was the gangue material, up to the topmost portion of the cylinder, where it over-

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flowed into a receiver. The heavier portion, being the mineral, sunk in the presence of the uprising current of water, and was collected in the bottle at the lower end of the cylinder.

Q. 132. And in what condition was the mineral collected in the bottle at the lower end of the cylinder?

A. The mineral that was collected in the bottle at the lower end of the cylinder was in a decidedly pure state, containing very little gangue material, or insoluble.

Q. 133. On Saturday you performed an experiment with 25% of oil, petroleum distillate, relative to ore, which was Utah Copper retreatment classifier overflow. I won't ask you to perform another experiment of that kind, but have you done a similar demonstration with Butte and Superior ore?

A. I have conducted a similar demonstration using the Butte & Superior ore.

Q. 134. Can you give an approximate description of the details of that experiment?

A. In that experiment that I performed I used 300 grams of Butte & Superior ore, 1500 c.c. of water, at a temperature of about 30° Centigrade, one c.c. of concentrated sulphuric acid, 75 grams of kerosene, which is <sup>the</sup> equivalent of 25% of oil relative to ore. This experiment was performed in the square glass jar machine, and the agitation was continued for approximately three minutes at a speed of about fourteen to sixteen hundred revolutions per minute. The result of that experiment was a very copious froth contain-

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ing the zinc sulphide mineral, and showed a very good degree of concentration.

Q. 135. Can you give descriptions of the demonstrations that will be illustrative of the present mill practice on the Butte & Superior ore; I don't think I will ask you to do them, but I would like you to give the details of the operations, one in using less than 1% of oil and another more than 1%.

A. I can. I have performed several experiments of that nature and I can repeat the same if so desired.

MR. WILLIAMS: I think that if we are going to have any testimony as to experiments which illustrate the operation of the Butte & Superior—While I don't want to take up the time of the court unnecessarily—still, it does seem to me that we ought to have the experiment rather than the secondary evidence of the description by the witness.

MR. SCOTT: Well, I will have Mr. Dosenbach perform the experiment if you wish. My idea was to have him give the laboratory proportions and procedure and leave it with you if you wanted to consume the time to see them.

MR. WILLIAMS: All right, we may do it that way.

MR. SCOTT: I might suggest at this time that we have thought it would be very informing if the court would visit the Butte & Superior mill simply for an ocular impression of the process on a large scale. If the court is willing we would be very glad to ar-

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range for that. I am not informed as to whether the court has actually seen the flotation operations on a large scale or not.

THE COURT: No, I haven't. Well, I don't know —of course I am hopeful that I will be sufficiently educated for a metallurgist before I get through; but whether I am yet ripe enough to judge by looking at the process I am not sure. Do you think it will assist me?

MR. SCOTT: It always gives me more of a grasp of things of this kind if I can see them in actual operation. There are many things that we have to explain that will be more clear by seeing it. Of course in the mill these froths do not accumulate in these masses that we see here, and then have to be taken off all at once, but there is a constant movement through the cells, and the froth is constantly overflowing a lip as it is being formed.

MR. GARRISON: I would like to suggest to your honor, that if you do think well of inspecting of the procedure at the Butte & Superior, that you, at the same time inspect the proceedings at the Timber Butte mill, which is using ore from the same vein, and is avowedly using our process, being a licensee of ours, and where the amount of oil is from one-half to three-quarters of a pound to the ton of ore.

THE COURT: Well, some time during the progress of the hearing we will try and do that.

Q. 136. Now, could you give a description of what

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you think is the best illustration of the procedure at the mill?

A. A description of the process that would be applied in a small apparatus as being descriptive of the operations at the Butte & Superior plant would be an experiment carried out in the Janney machine, which is this machine that I refer to, the Janney Flotation Machine. This is the machine that is now being used at the Butte & Superior flotation plant, and in carrying out the experiment I would use about 30 pounds of oil to the ton, or  $1\frac{1}{2}\%$  of oil mixture.

Q. 137. What are the ingredients of the mixture. I take it it is the same mixture used at the Butte & Superior?

A. Substantially so, yes. 70% of fuel oil, 18% of pine oil and 12% kerosene. The proportion of ore to oil that I would use would be 400 grams of ore and about 2000 c.c. of water. I would use sulphuric acid and copper sulphate, as both are being used, and the exact proportion of sulphuric acid to 400 grams of ore would be .9 of a cubic centimeter. I would also use 1 c.c. of copper sulphate solution.

Q. 138. What does the copper sulphate do?

A. The copper sulphate assists materially in the recovery and grade of the concentrate produced. It assists the acid in its action.

Q. 139. Is the use of copper sulphate to your knowledge recommended by any of the literature of the art?

A. Yes, I have found in the Everson patent the use of copper sulphate is recommended as being one

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of the salts that can be used in place of the sulphuric acid or together with the sulphuric acid. It is very distinctly brought out, the use of the various salts in the Everson patent. With 400 grams of ore I will use 6 grams of oil mixture, which is equal to 1½% relative to the ore, or 30 pounds per ton of ore. This operation carried out in the Janney machine will show to a great extent, and as near as possible the laboratory method setting forth the actual practice.

Q. 140. This Janney machine comes nearer illustrating the mill operations than the jar, doesn't it?

A. Decidedly so, yes, because during the operation of the Janney machine the froth may be taken out as it is being agitated and brought up to the surface; consequently it is not necessary to stop agitation and let the froth rise to the surface and then be skimmed off; but it can be done as it is being agitated and flowing into the spitzkasten—the froth can be taken off. Now, it might be well to show a comparison of the two experiments, using the same proportions of oil to ore and reagents in the square glass jar, as against the Janney machine.

Q. 141. Have you the motors so that you can do both at once?

A. Yes, I think I can do both at once.

Whereupon further was adjourned until 2 p. m.

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MR. GARRISON: With the permission of the court, may I ask for the response of Mr. Kremer as to the result of his search?

MR. KREMER: I beg your pardon, Mr. Garrison, I entirely forgot to inquire. I will go and inquire immediately.

MR. SCOTT: Mr. Dosenbach was about to perform two experiments, if your honor please, representative of the oil mixture in the quantities used in the Butte & Superior plant, and he has arranged to do both of these experiments at once to save time that would be consumed by doing one after the other. He will do one of the experiments in the Janney machine, and in doing it he will try to take off part of the concentrate first, representing what is taken off in the real machine first, and then in a separate basin will take off the rest, which will represent the middling, or the material which is returned. In this glass jar machine he will use the same mixture and the same ore, to illustrate the difference between those two ways of doing it.

(Test in Janney machine, test No. 34. Test in glass jar machine, test No. 35.)

THE WITNESS: I think I have stated what I will use; the percentage of the oil mixture in each instance will be  $1\frac{1}{2}\%$  relative to the ore. I will start the square jar machine and let it continue while carrying on the operation in the Janney machine, and by the time the latter is finished the other will be finished.

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(Both machines running.)

THE WITNESS: What I am doing now, scraping off the froth from the Janney machine, represents what the scrapers do. In the actual plant there are scrapers which carry off a little of the froth every time it comes around; otherwise it would pile up and come over the sides. I will stop it now and take this first concentrate, if anybody wishes to see it.

This second basin, its contents represent the middling, or approximately so; although, in the lower stages of the actual machine we take the middling product after taking off the richer product that comes off first. This of course is a very much lower grade froth than is the actual case in the machine. In the mill the lower machines take off the middling, there being less mineral in the ore at that time. As a matter of fact in an operating plant we have the water level raised much higher than this; in the latter part of the machines it is higher than in the first part of the machines, which I show now. (Adding water.) Now, this is the water level about up to this point, and in the last cells the water level is much higher. This shows a froth coming off now in which there is very little mineral, which can be seen by the clear bubbles. There being very little mineral present, there will not be much mineral in the froth.

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(Going to the glass jar machine.)

Here is the froth that was made in the glass jar machine with the same percentage of oil. The only thing that we had reference to in this experiment was to show—was that there might be criticism about some of the oil going off during the first operation in the Janney machine, and this experiment is to show the similarity between the froths.

Q. 142. MR. SCOTT: What causes the bubbles to break down in the Janney machine so quickly?

A. There is no more agitation.

Q. 143. And what is left there?

A. There is very little mineral left; most of the mineral has been taken off, consequently this is a very good tailing, which I should be glad to have analyzed. The bubbles and possibly the froth before the machine was stopped showed that they were clear, and that very little mineral was contained in them; consequently when the agitation was stopped, the bubbles broke down.

That will complete the experiment, with the exception that I would like to take off the tailings at this point. We will number this station No. 1, the concentrate, and this will be the middling, No. 2, and I will also give one-half of these products to the plaintiff. Now, we will take out the tailing from the Janney machine and see what it looks like. (Taking out material from Janney machine.)

Now, I will put some of this fine slime into this other pan, since one pan will not hold it all, and

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later we will combine the two of them and half will be given to the other side. Now, what is in this pan shows very distinctly the poorness of the tailings. It is very light in color, and we will assay that and see just what it contains. It shows that the tailings are comparatively free from mineral. If it contains very much mineral after this action, the mineral would be noticed very distinctly and it can be seen that it has the same consistency throughout and is very light in color, showing that the mineral is gone.

Q. 144. Mr. Dosenbach, you better briefly describe the complete operation performed. I am afraid it is a little fragmentary the way it is in the record now.

A. The two operations that I have just completed are as follows: The one operation was carried out in the Janney machine and purports to set forth the operation as conducted at the Butte & Superior plant inasmuch as laboratory apparatus is concerned. The proportions of material used in the Janney machine experiment was 400 gms. of Butte & Superior ore containing approximately 15.9 per cent zinc; 1900 c.c. of water was used at a temperature of 30° C., 0.9 c.c. of concentrated sulphuric acid was used, which is equivalent to about 8 lbs. of sulphuric acid per ton of ore. 1.0 c.c. of copper sulphate solution was used which is equivalent to about 0.1 pounds of copper per ton of ore, metallic copper. 6 gms. of oil mixture was used. This oil mixture consists of 70% fuel oil, 18% pine oil and 12% kerosene. The agitation

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consisted of approximately thirty seconds of mixing the oil with the ore and other reagents, and one minute and a half approximately for the period during which the concentrate was taken off and two minutes and a half constitutes the period during which the middling was taken off.

MR. WILLIAMS: Will you describe what you did in that period of the operation where you said there were 30 seconds of mixing.

A. During the period of thirty seconds of mixing the ore, oil, acid and sulphate were mixed by the agitation of the impeller blades in the machine for a period of thirty seconds.

Q. 145. And you confined these materials to the agitating chamber, did you not, during that particular operation?

A. I did, yes, the same as I would put them in the agitating mixer and add additional water later to fill up the spitzkasten. After discontinuing agitating the mixture and the middlings having been removed, I removed the tailings and all products will be assayed to determine their value. In the square glass jar machine at the same time that I performed the experiment in the Janney machine I performed an experiment wherein I used 300 gms. of Butte & Superior ore containing approximately 15.9 per cent zinc; 1500 c.c. of water at a temperature of 30° C.; 4.5 gms. of oil mixture consisting of 70% fuel oil, 18% pine oil and 12% kerosene, this oil mixture being the same as I used in the Janney machine during the experiment

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that I performed in it. I also used 0.81 c.c. of copper sulphate solution which is approximately 0.1 pounds metallic copper per ton. I used .67 c.c. of concentrated sulphuric acid, which is equivalent to approximately 8 lbs. or 8.25 pounds of sulphuric acid per ton of ore. The agitation was continued for the same length of time as the total agitation in the Janney machine experiment. After discontinuing agitation in the square glass jar machine a highly mineralized froth formed on the surface, being composed of zinc sulphide and innumerable air bubbles. It shows a very good froth and the tailings as they have settled now are comparatively clean but the structure of the froth itself on the surface shows very distinctly the number of air bubbles that are present (exhibits sample to the court).

Q. 146. MR. WILLIAMS: I have no note of the temperature that you used in the Janney machine experiment?

A. 30° C.; 30° in both experiments.

Q. 147. MR. SCOTT: What would happen if you were to make a froth with say .2 per cent pine oil and then were to add enough to bring it up to one and one-half per cent and agitate again?

A. Well, I haven't done any experiment like that myself, I couldn't say—using pine oil?

Q. 148. Pine tar oil?

A. I have with pine tar oil, yes, sir.

Q. 149. Now, what would happen with pine tar oil?

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A. I have made an experiment like that and was curious to find out just what the condition—just what the addition of more pine tar oil would do after obtaining a result with a small quantity, to see whether there was any great difference between the froth that was obtained with a small quantity, whether a froth would be obtained with a ~~large~~ quantity, over one per cent, and to note whether there was any difference between the two, and I made a very interesting experiment just that way in the cone Gabbett machine, the machine that I used this morning in court to demonstrate the Cattermole process.

Q. 150. Then I think I will ask you to do that one more experiment, and then we will be through, showing the formation of this froth with .2 per cent of pine tar oil and after getting that froth simply pour in enough more to bring it up to one and one-half per cent and aerate and agitate it again?

A. I can perform that experiment very shortly.  
(Performing test No. 36.)

MR. KREMER: Mr. Garrison, while the experiment is being performed we can perhaps save some time. I have all of the vouchers here that we have in our possession—that is that we have been able to locate—I assume that they are all here because they cover a considerable period of time. Now, which of them do you desire to use.

MR. GARRISON: May I see them.

MR. KREMER: I will give them all to you and just put them in order and let me know.

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MR. GARRISON: I may put these in at some future time.

MR. KREMER: I can't urge you as to when you will put them in, but I wish you would look them over and use what you want to and return what you don't want.

MR. GARRISON: I will return them presently.

MR. KREMER: Those that you don't offer we will.

MR. GARRISON: I intend to offer all of them.

Q. 151. MR. SCOTT: Now, add enough to bring it up to one and one half per cent, that would be thirty pounds per ton?

A. Yes.

MR. SCOTT: Your honor will notice on top of this froth, the appearance of it, that is with the small quantity of oil.

Q. 152. MR. SCOTT: Now, suppose you go right ahead on that if it has stood long enough.

Q. 153. What difference do you notice between the froth of that with the  $1\frac{1}{2}\%$  approximately, and the one with 0.2 of one per cent?

A. The froth with  $1\frac{1}{2}\%$  approximately is of twice the volume that it was with the 0.2 of 1%. The agitation is about the same, and it shows plainly that there has been more mineral recovered by the addition of the extra amount of pine tar oil over and above what was in it at first, the 0.2 of 1%.

Q. 154. What do you say in regard to the produc-

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tion of froth with the added amount of oil as compared with the first case?

A. It is very similar; in fact the air bubbles on the side can be noticed, and the structure of the froth. There are a number of instances and places where the air bubbles are resting against the glass and are free from mineral, having discharged themselves by contact with the glass; that is noticeable all around. The froth with <sup>0.2</sup>~~.02~~ of 1% was 1 inch in thickness, whereas this froth is about an inch and a half. These bubbles can be seen, and also the structure of the froth with this magnifying glass.

Q. 155. State what machine this was in, for the record.

A. I have stated that this machine that I performed the experiment in is a cone Gabbett, the same one that I performed the experiment in this morning of the froth and the granules separately. I wish to state that my intention was to increase the oil from two-tenths to one and a half, but in weighing it out I used more than the amount necessary to make one and a half, consequently the total amount of oil used in this experiment was 1.62%. I originally used 0.615 grams of pine tar oil in the first part of my experiment, and produced a froth of from three-quarters to one inch in thickness upon agitation. This froth was highly mineralized, containing zinc sulphide. I then added, after three minutes' agitation, which was the total length of time of agitation for the first part of the experiment, 4.25 grams of the same oil, and

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continued agitation for three minutes. The total amount of oil was 4.865 grams, or 1.62% relative to the ore content.

Q. 156. BY MR. WILLIAMS: Have you given all the particulars of temperature and speed of agitation?

A. I will do so. It might be advisable to take off enough of the concentrate froth so as to give both parties an opportunity for analyzing the same so as to determine as to the purity and the grade.

MR. SCOTT: Let the record show that some of the froth was taken off and offered to plaintiff's counsel.

Q. 157. MR. SCOTT: Have you finished?

A. I think so, but I don't know whether I stated exactly what was used in regard to ore. I used 300 grams of Butte & Superior ore, containing about 14.8% zinc. I used 1250 c.c. of water at a temperature of 35° C. The amount of sulphuric acid used was 0.5 c.c. The agitation in each instance was carried on for three minutes at about 1750 revolutions per minute.

Q. 158. I believe you have prepared some statements of the operations of the Butte & Superior Company with larger and smaller amounts of oil. Can you produce such a statement for the period from 1913 to date?

A. I have a statement showing the results.

Q. 159. Can you supplement this statement by

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information regarding individual days operations if called upon to do so?

A. I can.

Q. 160. Were the operations during this period under your supervision—or part of this period?

A. From May, 1913, up to the present time, they were.

Q. 161. From May, 1913; that omits the first quarter?

A. That omits the first quarter of 1913, which is included in this record.

Q. 162. You have the records for that first quarter that you can refer to if counsel should want some information about the first quarter of 1913?

A. Yes, we have the records the same as we have for the succeeding period.

MR. SCOTT: I offer in evidence the table entitled "Butte & Superior Mining Company, Flotation Operations."

Table admitted without objection, marked DEFENDANT'S EXHIBIT No. 158.

Q. 163. The first column entitled "float. plant feed, ore to float. plant" just explain what these headings mean, will you, Mr. Dosenbach?

A. The first column, "Float. plant feed" under which is added "float plant. Dry tons and per cent zinc."

Q. 164. What is the difference between these two

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expressions, "Float. plant feed" and under it "ore to float. plant"?

A. "Float. plant feed" means flotation plant feed; which also means ore to the flotation plant.

Q. 165. Mean the same thing?

A. They are synonymous, only it is to make less confusion. That is the actual ore that goes to the flotation plant.

Q. 166. That is the original material that goes to it?

A. The original material.

Q. 167. Now, the next is "flotation machine feed" and under it "ore to flotation plant plus circulating middling treated in flotation"?

A. That is the original material plus the circulating middlings which is present in the flotation plant itself.

Q. 168. Now, in that column which is entitled "Percentage zinc" under the—there seems to be no entries until the fourth line from the bottom. I presume that material was not assayed for zinc during that period?

A. Yes. For most of the time, and I can supply that for every day that we have it for, and for this period. But I haven't had time to make it up for these periods. It was left out by mistake.

Q. 169. But you can get it?

A. I can get it because we have daily assays on each day and I will supply it to fill out this sheet.

Q. 170. Now the next column "flotation concentrate,

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tonnage and per cent zinc" seem to need no explanation. That is simply what is indicated there?

A. Yes.

Q. 171. As well as "per cent zinc" the same. You might explain again the difference between this apparent and estimated recovery.

A. The apparent recovery and the estimated recovery are both given in these tables. The apparent recovery is the recovery that is secured from the assays of the head, tailings and concentrate by the formula which takes into consideration the assay of each one of the products. That formula is the concentrate assay times the head minus the tailing assay divided by the head assays times the concentrate minus tailings assay. The estimated recovery as given in the sheet is the amount of metal recovered in the concentrate divided by the amount of metal in the heading. That takes into consideration the pounds of zinc in the concentrate as compared to the pounds of zinc in the heading.

Q. 172. The acid column is sulphuric acid of course?

A. I think they need no explanation. It is merely the pounds of acid per ton and the pounds of oil per ton. That is the amount of oil added to the original ore.

Q. 173. "Per cent oil in ore and circulating middlings treated in flotation" that is an assay figure, I take it?

A. Per cent oil in ore and circulating middling treated in flotation is determined by oil assays.

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Q. 174. By direct assay of the oil content?

A. Yes.

Q. 175. And that appears to be the same in the last four lines as well?

A. Next column "Pounds oil per ton contained in ore and circulation middlings treated in flotation" is merely the calculation from the analysis which is given in the column preceding. The per cent oil in concentrate, the next column following is by oil analysis of the concentrate, the per cent of oil in the tailings by oil analysis.

Q. 176. Can you just, for illustration, give us an example of how that figure "pounds per ton contained in ore and circulating middlings" how that is figured from the data in the preceding columns? For instance, take the entry February 4th to 28th, we have 25.4 entered under the heading I just read "pounds of oil per ton contained in ore and circulating middlings." Can you tell us just how that is derived from the preceding figures there?

A. That is derived from the preceding figures by multiplying the preceding figure by twenty, there being twenty pounds of oil, equal to one per cent, in a ton. Consequently if the per cent oil in ore and circulating middlings treated in flotation is equal to 1.27 per cent, then it is merely a matter of calculation to determine how many pounds 1.27 is equal to.

Q. 177. The only difference between these columns is one per cent and the other is pounds per ton?

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A. Yes.

Q. 178. Well, have you any figures in this table —well now, take these two columns, one is percentage and the other one is pounds per ton. Where is the sample taken for assay which gives the oil here, 1.27 per cent for instance?

A. The sample is taken of the feed before it enters the machine.

Q. 179. That is after the middlings and initial feed have come together?

A. Yes, exactly so.

Q. 180. There is no calculation then about determining the total amount of oil per ton of total solids? It is simply a direct assay?

A. That is all; there is no calculated amount.

Q. 181. The calculation you refer to is merely multiplying the per cent by twenty to get the pounds per ton?

A. That is all.

Q. 182. Have you ever checked up the amount of oil which was supplied to the feed with the amount discharged in concentrate and in the tailings?

A. During the course of our operations at the plant I have frequently checked up those figures.

Q. 183. And how closely do they come, approximately?

A. Well, I have found that they would come very close to the amount of oil actually added and equal very closely, the amount of oil contained in the concentrate plus the tailing.

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Q. 184. Can you give us an example of a calculation of that kind?

A. Yes, I have made a calculation in the period from February 4th to 28th, which is the first period that contains the oil analysis on the concentrate and tailing. As will be seen by the report, there was during that period from February 4th to 28th inclusive, 20.07 pounds of oil actually added to the ore as it came to the flotation plant. That is equal in round numbers to one per cent, the amount of oil actually added then for this period based upon the tonnage of 36,262 dry tons, was 725,240 pounds of oil used during that period.

Q. 185. The tonnage was 36,262?

A. 36,262 dry tons.

Q. 186. Multiply that by your 20.07?

A. Yes. The amount of oil contained in the concentrate plus the tailings was equal to 722,760 pounds.

Q. 187. Have you figured that percentage of error by deducting one from the other?

A. That is very easily done. That error is approximately three-tenths of one per cent.

Q. 188. Have you figured other periods to see if they come within the same order of accuracy?

A. Well, I figured the next period also.

Q. 189. And how close did that one come?

A. That came within practically one per cent.

Q. 190. And how close did they come?

A. They came within practically one per cent.

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Q. 191. That is the period from March 1st to 20th?

A. March 1 to 20, correct. I figured the next period and that came within approximately ten per cent, showing a variation. And the next period.

Q. 192. That is April 1 to 15, the next one?

A. Yes. The next period showed about fourteen per cent approximately. If you wish, I can figure out the exact amount, but that is approximately given from the figures. And, for instance, I have the last period April 1 to 15, that being 578,290 pounds or as against 502,850 pounds contained in the tailings plus the concentrate.

Q. 193. Was there any reason for that increase of error in these last two periods?

A. There was no reason that I know of, no.

Q. 194. I do not see the year 1917 on this left hand column here under the head "period." We have 1916, three quarters, that year, and then December 22nd to January 7th. I suppose that is where 1917 begins, that period extends over from 1916 over into 1917?

A. Yes, sir.

Q. 195. The years are not separated then, are they?

A. No, the third quarter of 1916 is on there separate from the year 1916 on account of having started a portion of the flotation plant during the month of December, 1916.

MR. WILLIAMS: Mr. Scott, I suggest that on

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the exhibit in evidence you add dash and sixteen after December 22nd, and a dash or inclined line and 17 after January 7th. I have made that change.

MR. SCOTT: That will read then December 22nd, 1916 to January 7th, 1917. Will you consent? I will simply change it.

MR. WILLIAMS: I have changed it. I have the exhibit.

Q. 196. MR. SCOTT: Taking the three entries beginning with the one for the year 1913, that is the fifty horizontal line, up to the year 1914 and 1915, that is the entries for these three years, I find that the gain of the concentrate improves somewhat, 47.8 for 1913, 53.03 for 1914 and 54.82 for 1915. Can you state the causes that led to this improvement?

A. Well, the chief causes were the improvements in the plant and the operation and the mechanical changes that were made, changes in the flow sheet and also the change in mechanical conditions whereby our operating conditions were made better.

Q. 197. I don't suppose you remember in detail all of these changes? Do you remember any of them?

A. Well, in May, 1913, as I think I stated before the plant was down for a period of six days during which time a complete remodeling of the flotation machines occurred. Then during the third quarter of 1913 more changes were made, and also in the fourth quarter of 1913 more changes were made, and during the year 1914 at various intervals changes

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were made in the flotation plant that entirely improved results—for instance, in 1913, speaking of the second quarter, we had four spitzkastens. Later on another spitzkasten on each rougher was added and continued that way until we had ten spitzkastens for each rougher. Then an additional cleaner was added—I may have a record of that right here, of the exact date. It was started rather late in 1913, a new cleaner was started in November, which provides for two cleanings instead of one previous to that time. Then in 1914 general mechanical changes throughout the flotation plant and the disposition of the feed and so forth between one cell and another was instituted and five additional spitzkastens on each one of the roughers and later on the change from five passes to seven passes, which means that the feed has seven different agitations throughout its course through the machine. Then in 1914, the latter part of 1914 we started installing again another type of machine which was the Janney machine, and started the first unit in 1915, during the month of January, and the whole plant was in operation by May 1st, 1915. So that accounts particularly for the improved results in the grade of concentrate as well as the recovery for the period from January, 1913, through and including December, 1915.

Q. 198. I notice in the period March 1st to 20th, 1917, the third line from the bottom, that the tailings ran 1.54 zinc, and the apparent recovery was 90.84, concentrates, 47.50. Will you point out on this table the earliest date when a result equal to that was ob-

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tained—equal in efficiency, taking into account the grade of the concentrates and the recovery.

A. Well, the period that I should say nearly approximates it is the year 1915, when the recovery was 90.18%.

Q. 199. That was substantially the same order of recovery?

A. Also the grade of concentrate was higher during the period of 1915 than during the period of March 1st to 20th, 1917.

Q. 200. How about the loss in the tailings?

A. The loss in the tailings was of the same character during the period of 1915 as compared with the period of March 1st to 20th, 1917; I think that is the period which more closely corresponds.

Q. 201. Now we have here recorded 1913, 1914 and 1915. So that would be the third year of operations recorded on this sheet?

A. Yes, sir.

Q. 202. When the results you say were comparable with those obtained from March 1st to 20th. Now, from March 1st to 20th you were using how much oil?

A. The actual oil added to the ore going through the flotation plant was 21.3 pounds per ton.

Q. 203. During the year 1915 it was 1.49, was it not?

A. 1.49 per ton.

Q. 204. Now I see on this sheet it is recorded the amount of oil added per ton of ore. Do those figures represent the total amount of oil present?

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A. No, the total amount of oil present is much larger than that designated under the column "Per ton Ore to Flotation, Pounds." As shown by the figures in the column preceding it, "Pounds Oil Per Ton Contained in Ore and Circulating Middlings treated in flotation."

Q. 205. As I understand what you have stated, under the heading "Oil Pounds," those figures are the actual weight of oil added?

A. Absolutely.

Q. 206. Determined by actually weighing and by actually sampling and estimating the tonnage of ore going through the plant?

A. Yes.

Q. 207. And that figure giving the percentage of oil in the ore in the circulating middlings is the result of an assay of the amount of oil in the material going through these flotation machines?

A. Exactly so.

Q. 208. So there is no calculation about any of these figures; they are all determined by weight and measure?

A. Yes.

Q. 209. And then, according to these figures, will you just make a comparison between the amount of oil added for each of these periods and the amount found to be present by assay, using the figures per ton as they seem to compare?

A. During the period from February 4th to 28th in-

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clusive, there was 20.07 pounds of oil added to the feed to the flotation plant, and 25.4 lbs. of oil present in the feed to the flotation machine.

Q. 210. And it was during that period that you just said the figures checked up within about 1%?

A. They checked up less than 1%. In the next period, from March 1st to 20th inclusive, there was added to the ore going to the flotation plant 21.3 lbs. of oil per ton, while there was in the flotation feed—

Q. 211. Including the middlings?

A. —to the machines, which includes the middlings, 30 lbs. of oil per ton.

Q. 212. During that period how close did you say the assays checked with the oil added?

A. About 1%.

Q. 213. Have you any explanation of the fact that during that first period, February 4th to 28th, the oil added was 20.07 lbs., and the oil present by assay 25.4, showing an increase of about 5 lbs. of oil, or a little over, while during this next period, March 1st to 20th, the difference between the oil added and the oil present as assayed is the difference between 21.3 and 30, or about 8.7 lbs.?

A. Well, my opinion now would be that it was due entirely to the operations. There was possibly more oil contained in the feed at different times that was sent back for circulation, and the mechanical conditions that existed, as I remember it, during that time, were somewhat erratic, and we were remodeling

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the plant also at that time, and there was not a great length of time wherein the actual operating conditions were the best, and where the feed that was returned, or the middlings that was returned was always uniform, but it averaged up pretty well. Some days we would make it higher than others. That may account for it.

Q. 214. Do you vary the number of cells in a series that return the concentrate as middlings, or do you run pretty steadily?

A. At times we vary that, depending on the material we are treating, and in order to relieve our elevators, should anything go wrong with them.

Q. 215. The machines are fixed so you can switch them from middlings to rougher concentrates?

A. Yes, they are.

Q. 216. What is your information as to the relation of tonnage returned as middlings and tonnage originally sent to the flotation machine; is as much material returned as middlings in circulation as is fed to the machine? That could hardly be, could it?

A. Yes; and at times there is more middlings than there is actually fed to the flotation plant.

Q. 217. More circulating load than the original supply?

A. Yes, but in circulating the middlings in our plant it joins the original feed and is elevated by a 36 inch elevator, and then distributed to the machines, consequently we have no distinct circuit of middlings and original ore remaining.

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Q. 218. I think there you have daily records arranged by months for several months. The January record begins on the 9th; how is it that it does not begin on the first?

A. The reason for that is that on that day we commenced operations using more than 1%, or 20 lbs. of oil per ton of material.

Q. 219. And you began your daily compilation from the time the large amount of oil was used in the whole plant?

A. Yes, sir.

MR. SCOTT: I offer in evidence tabulation of daily results for the month of January, 1917.

Admitted in evidence without objection, marked DEFENDANT'S EXHIBIT No. 159.

Q. 220. Now, in this tabulation I find the heading "Flotation Machine to Date; Ore Flotation Plant Plus Circulating Middlings Treated in Flotation." The samples for those assays I suppose is taken between the sluge tank and the head of the machine, is it?

A. That sample is taken just before the feed is distributed to the various machines; it contains the original ore and the circulating middlings.

Q. 221. Now, take the column headed "Percent of Oil in Ore <sup>and</sup> Circulating Middlings Treated in Flotation;" that is determined by a correct assay of the material I presume?

A. It is.

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Q. 222. The same as in the case of the other tabulations?

A. Yes.

Q. 223. The next is simply computed from the percentage?

A. Yes.

Q. 224. You have a column here also, "Oil Used," with a series of numbers. Have you a key for those numbers which explains what the oil mixture is?

A. Yes, I run all my oil mixtures by numbers.

Q. 225. Does the key run through for the days on which the statement for January is made?

A. Yes.

Q. 226. It runs all through?

A. All through.

MR. SCOTT: I offer paper headed "Butte & Superior Mining Company," with the notation below, "Statement of Percentage of Oils etc."

Admitted in evidence without objection marked  
DEFENDANT'S EXHIBIT No. 160.

Q. 227. You may explain the terms noted at the heads of the columns of oils there. What kerosene is that?

A. Commercial kerosene.

Q. 228. And the Jones crude?

A. That is Jones crude from Kansas; it is commercially called Jones crude.

Q. 229. The No. 1 creosote?

A. That is a hardwood creosote.

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Q. 230. The No. 2 creosote?

A. That is also a hardwood creosote.

Q. 231. Fuel, I suppose that means fuel oil?

A. Fuel oil from a petroleum base.

Q. 232. Pine oil next, No. 4 Barrett? What is that?

A. That is a coal tar distillate.

Q. 233. What kind of tar?

A. Coal tar.

Q. 234. Paraffine base; what does that mean?

A. Crude paraffine base oil.

Q. 235. Now, I believe you have similar statements for February and March, giving the particulars for each day?

A. I have.

Q. 236. And the testimony you have just given regarding the explanation of these headings, and regarding your supervision of operations applies to these operations recorded in February and March?

A. Substantially so, yes.

MR. SCOTT: I offer these statements in evidence for the months of February and March, 1917.

Admitted without objection, statement for February marked DEFENDANT'S EXHIBIT No. 161, statement for March marked DEFENDANT'S EXHIBIT No. 162.

Q. 237. I notice Mr. Dosenbach, that in January the average amount of oil added per day was 14.75, appearing at the bottom of the column in the average line.

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A. Yes, it is.

Q. 238. And that in February the amount of oil added per ton averaged 19.33?

A. Correct.

Q. 239. Then considerable more was added in February than in January?

A. That is so.

Q. 240. Now, looking at the column "Pounds Oil Per Ton Contained in Ore and Circulating Middling Treated in Flotation," which I understand is determined by assay, for February it averaged 23.6 and for January averaged 33.4. Why did the oil present exceed the amount added so much more in January than in February?

A. Well, as I stated before, that may be accounted for in the operation of the machines themselves, and also in the character of the oil that was used. Now, as will be noticed in the last column here, under oil used, and the number, you will note that various mixtures were used, and almost every day they were changed, consequently the difference in the character of the oils themselves may account for some of that variation between the two months.

Q. 241. Now, I believe you have operated a part of the flotation apparatus separate from the remainder for some periods of time. Have you a statement setting forth the operations of that segregated unit?

A. Yes, sir.

(Recess.)

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Q. 242. You stated that you had a sheet recording the operations of this independent unit, didn't you?

A. I have.

Q. 243. And I find attached to my copy a paper headed "Butte & Superior Mining Company" with the statement: "Below is a statement showing the percentage of oils in the various mixtures, used on the three pyramid machines, while running them on experimental tests," and I presume that bears the same relation to these separate machines that the other oil sheet did to the regular operations of the mill?

A. It does bear the same relation.

Q. 244. These experiments were conducted, were they, or these special operations by you or under your supervision?

A. They were.

MR. SCOTT: I offer in evidence the tabulated statement headed "Butte & Superior Mining Company, flotation pyramid machines."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 163.

MR. SCOTT: And I wish now to offer in evidence what I will call the oil sheet, headed "Butte & Superior Mining Company," "Below is a statement showing the percentages of oils in the various mixtures, used on the three pyramid machines, while running them on experimental tests."

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Document admitted in evidence and marked DEFENDANT'S EXHIBIT 164.

Q. 245. What was the purpose of separately operating this section of the plant?

A. The main purpose and chief purpose was the fact that we didn't have sufficient oil to operate the entire plant.

Q. 246. With the quantities and kinds of oil you wanted to use?

A. Yes, over one per cent or twenty pounds.

Q. 247. And what was the difficulty in getting a sufficient supply of these different oils?

A. Well, we had considerable difficulty in getting them on account of railroad facilities, it was impossible to get it here any sooner than on the 9th of January.

Q. 248. Was there any difficulty aside from the transportation difficulty?

A. Yes, one of the main difficulties was getting the oil.

Q. 249. Getting the oil?

A. Yes, being able to get it.

Q. 250. You mean there was not a supply available to be purchased?

A. Yes.

Q. 251. You might describe briefly what this separate section of the plant consists of, and in a general way how it was operated?

A. Well, this sheet or report sets forth the operations of an independent pyramid machine. There is a

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column where this machine number is shown and under it is the number of the machine that was in operation.

Q. 252. Now, when you say "pyramid machine" just what do you mean to designate by the word "pyramid"?

A. Well, the word pyramid is taken from the machine itself, it being a pyramid shape.

Q. 253. Simply similar to several of these machines of this Janney type, and each one higher than the preceding one, so that you have a gravity flow from one to another?

A. Exactly so, yes.

Q. 254. That is all that is meant by the word "pyramid?"

A. Yes.

Q. 255. And that is the regular arrangement of the entire plant, isn't it, that gravity or pyramid arrangement?

A. That is.

Q. 256. Now, under the column "machine number" on that first day, appears the figure "2." That is the number of the single machine or cell or the number of the whole set of these machines that are arranged one above the other?

A. That is pyramid No. 2 which consists of seven of the cells.

Q. 257. And each of these so-called pyramid machines consist of seven cells?

A. Exactly so.

Q. 258. And then each of these numbers in the col-

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lumn "machine No." indicates some particular group of seven machines that is being used for this test here recorded?

A. Yes, sir, it does.

Q. 259. So that all the tests were conducted on a machine consisting of seven Janney cells?

A. They were.

Q. 260. And they were these cells of the double spitzkasten type, weren't they?

A. They were.

Q. 261. Now, is there anything in these column headings that is different from the phraseology that you explained in connection with the other report?

A. Well, the first column, "machine feed," with the "ore to machines," that consists of a portion of the slime and a portion of the tube mill discharge.

Q. 262. Where do these slimes come from?

A. The slimes were regularly produced at the plant.

Q. 263. From the gravity concentration?

A. Gravity concentration end of the mill, and the tube mill product is the finely ground material that is produced in the mill itself or the concentrating end of the mill and is ground to sufficient size to go to flotation. It is sand tailing from the concentration end of the mill.

Q. 264. Now, in this column "machine feed" "ore to machines," "per cent zinc recovery," that percentage of zinc was obtained by assay, was it not, of the material fed, in this report?

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A. Yes, in this report, it was.

Q. 265. And so of course is true of the percentage of zinc in concentrate and headings, is it not?

A. It is. The apparent recovery is given but not the estimated recovery on account of not being able to obtain any definite weights or measurements of the concentrate produced.

Q. 266. That was because the concentrates were mixed up with the concentrates from the rest of the mill?

A. Yes, the concentrate produced in these machines was mixed with the regular concentrate.

Q. 267. And this "estimated recovery" is taken from actual weight?

A. It is.

Q. 268. Now under the general heading, "oil amount and analysis" we have a column "% oil in ore and circulating middling treated in machines." I presume that is obtained by assay from samples?

A. That is obtained by assay from samples taken.

Q. 269. After the—

A. (Interrupting.) Middling has been added to the original feed.

Q. 270. Yes, after they both come together?

A. Yes.

Q. 271. The next column simply converts the percentage into pounds?

A. It does.

Q. 272. "Per cent oil in concentrate" and "per cent oil in tailings" is found by what?

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A. By analysis.

Q. 273. The last column refers to the oil, kind?

A. Kind of oil used.

Q. 274. Now, is there a column here that tells how long these different operations lasted, or were they all for the same period?

A. They were for 24-hour periods on the days designated, and some days may have not been entirely 24 hours for the particular pyramid machine named if it was necessary at times to shut it down for repairs for an hour or two, possibly; but these are the actual results from these particular machines on these particular days and no other feed was put into that machine while it was not in operation on the material designated in this report.

Q. 275. The tonnages there give a pretty fair idea of the time that each operation was conducted, I suppose, dont' they?

A. Yes.

Q. 276. I see some of these tonnages run up as high as 240. That is probably a 24-hour run, would you say?

A. Yes, that was a 24-hour run, I should say, judging from the tonnage.

Q. 277. Now, what was the largest percentage of oil used in any of these operations—we will take on the basis of pounds of oil added, say, rather than on the basis of the analysis?

A. I find in this report that on the first day of January, 1917, there was 63.03 pounds of oil added.

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Q. 278. Yes. Now, running over the column "pounds oil per ton in ore and circulating middling treated in machine" I find 55.8 pounds of oil per ton. That figure is somewhat lower than the amount of oil per ton of original feed added. What would that indicate in regard to the amount of oil on the middling?

A. That would indicate that there was less oil in the middling being returned.

Q. 279. Less than 63.03 pounds?

A. Yes, and that the returned middlings contained a lower percentage of oil than say on—other days. There are a number—there are a few days like that in the other reports, in the monthly report by days, that show that same thing.

Q. 280. What were your recoveries and grade of concentrate and loss of zinc in tailings on that day, January 1, 1917, when you used 63<sup>0</sup><sub>3</sub> pounds of oil per ton?

A. The recovery was 91.72 per cent, and the grade of concentrate produced was 42.7 per cent.

Q. 281. And the tailings?

A. The tailings contained 1.51 per cent zinc.

Q. 282. Now, were the concentrates from that tailing marketed?

A. They were.

Q. 283. What would you say as to the recovery of zinc—as to the loss of zinc in the tailings and the recovery, as to their efficiency? That is 1.51, is that a good or a bad operation?

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A. That is a good operation showing a recovery of over 91 per cent.

Q. 284. Now, do any of these other assays bring out any matters of interest that you wish to comment on?

A. Well, I should say, selecting one above that, on the first day of January, 1917, on a different pyramid machine, #2 pyramid, the tailings assayed .5 per cent zinc, one-half of one per cent, making a recovery of 97.18 per cent zinc, showing a concentrate of 44.6 per cent zinc. I may add also here that the pyramid machines in operation as reported on this report consist of six cells and not seven, as the first cell was used as a cleaner.

Q. 285. What effect would that have on the operation?

A. Well, that would give six different agitations instead of seven, also six spitzkastens from which the froth was taken off, or twelve instead of fourteen, counting the double spitzkasten, or seven, counting the single spitzkasten, and also shows that there was only one cleaning operation of the concentrate that was produced by the rougher cell or the rougher pyramid consisting of six cells.

Q. 286. Did the concentrate from these specially operated pyramid machines have any further treatment?

A. They did not; they had no further treatment than the cells themselves, as far as these assays were concerned.

Q. 287. As far as the assays were concerned?

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A. Yes.

Q. 288. That is these operating assays that are here are from samples taken just when the concentrate left the pyramid machine?

A. Yes.

Q. 289. Now, what became of these tailings after they left the pyramid machine?

A. They went through the air cells down below, but they were mixed up with the tailings that were produced in other portions of the plant so consequently no assay could be determined after they left the air machine.

Q. 290. You didn't have any special air machine coupled up to this machine?

A. No.

Q. 291. About these other reports of general operations that you have testified about, are the tailing assays there made from tailings after they have gone through these air machines?

A. They were.

Q. 292. But in the case of these operations recorded on these special pyramids, the assay of tailings merely represents the tailings made by that pyramid?

A. Exactly so, yes.

Q. 292½. MR. SCOTT: I think that will be all unless you find something here that requires explanation, Mr. Dosenbach?

A. There is one thing I would like to explain about. In the January report by days for 1917, and that is on the 31st the apparent recovery was 87.12.

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Q. 293. What day was that?

A. On the 31st of January.

MR. WILLIAMS: Exhibit 159?

A. Yes.

MR. SCOTT: The apparent recovery you said was 87.12?

A. And the estimated recovery was 130.70. I think it would be well to enlighten you on that particular date. Now, that is due to being the last day of the month and for our general reports and our general method in use, on the last day we take a general summary of what our products has been for the month as compared to each day's measurements, and consequently it shows an under estimating for 20—or the number of days previous to the 31st. Now, in addition to that, on account of not having sufficient railroad cars to transport our concentrates it was necessary to stack quite a lot of our concentrate on our grounds or bins provided for that purpose, after they had gone through the filter plant, and so some of this material was not taken into consideration in each day's calculation, or each day's measurement. Consequently, it was necessary for a general cleanup of the month to take into actual account all of the products for that month, and we had to take it into consideration on the last day. So that makes the difference between the estimated—or accounts for the difference between the estimated and apparent for the 31st of January.

Q. 294. That is this estimated recovery is figured

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from the absolute weights of the concentrates, and their assay?

A. From the estimated weight and assay, yes.

Q. 295. But some days that estimate was not based upon all the <sup>n</sup>concentrates produced, and they accumulated during the month?

A. Yes.

Q. 296. So that the 31st day of the month got credit for some of the concentrates that had been produced previously?

A. Yes.

Q. 297. And to be absolutely accurate now I understand that some of this excess over one hundred per cent there or some of this excess should be distributed through all of these days, but that it is impossible to do it?

A. That is it exactly.

Q. 298. So that some of these estimated recoveries here are under statements, up to the 30th of the month?

A. Yes, it is more of a direct comparison, one day with another by the apparent recovery, but over a period of a number of days the estimated recovery should approximately check very closely with the apparent recovery.

Q. 299. The average for a considerable period would come close together?

A. Yes.

Q. 300. But on account of this accumulation of material why you couldn't figure out a comparison between individual days?

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A. Yes.

MR. SCOTT: I think you may cross-examine.

MR. WILLIAMS: Before commencing cross-examination I would like to say that we have been presented with tables of a number of experimental operations and have not had time to give them study and I would like to reserve the right to object to these experimental operations until we have had a chance to study them, being inclined to let them in if on further study we think they may be material.

Q. 301. MR. SCOTT: Mr. Dosenbach, these operations in this special pyramid machine, they were real, mill sized operations, weren't they?

A. Absolutely so.

Q. 302. They all entered into the product of the mill, which was marketed?

A. Yes, sir.

Q. 303. The only difference being that this part was separated for special operations?

A. As an independent and isolated circuit from the rest of the plant, but treating the same material as the rest of the plant did treat.

Q. 304. The concentrates were sold the same as all the rest of the mill?

A. Yes.

Q. 305. But it enabled you to keep track of the results without getting them all mixed up with the regular mill results?

A. Exactly so, yes.

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CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 306. Referring particularly to this table, exhibit 163. Now, "concentrates, percentage zinc," that was determined upon the concentrates after they had been delivered by the cleaner machine?

A. By the one cleaner machine which was on the pyramid that it represents.

X-Q. 307. You say the first machine was the cleaner machine?

A. Yes, sir.

X-Q. 308. By that do you mean the upper machine of the pyramid?

A. The first cell of that particular pyramid was the cleaner machine.

X-Q. 309. And that was the highest machine of the three?

A. Yes, sir.

X-Q. 310. So that the rougher concentrates from the other six machines were carried by an elevator, were they not?

A. No, by a pump.

X-Q. 311. By a pump?

A. Pump, centrifugal pump. It was necessary to pump it back up to this first cell. The original feed came into the second cell while the rougher concentrates were made on the first two cells and the middling on the next four; or it was so arranged that the next three

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could make a rougher concentrate or middling, either one and that rougher concentrate was pumped back again to this first cell.

MR. SCOTT: At this point, if I may interrupt, I would like to offer that in evidence so that it can have a number, and the record will show what you are referring to.

Diagram admitted in evidence and marked DEFENDANT'S EXHIBIT 165.

X-Q. 312. MR. WILLIAMS: That is the flow sheet that was produced and described on Saturday last? Is that right, Mr. Scott?

MR. SCOTT: Yes.

THE WITNESS: Yes, that is the flow sheet that I produced and described on Saturday. However, I will produce another flow sheet to show exactly as the materials are going today. That doesn't show everything complete, but for this reference we can use.

X-Q. 313. Now, I want to understand exactly the operations during these runs that are tabulated in Exhibit 163, and as I understand now on machines 2 and 3, you produce a finished concentrate?

A. Now, let me correct you on that. This is machine No. 1, and at that time this was machine No. 2, and at that time this was machine No. 8.

X-Q. 314. As you have marked them in pencil?

A. Yes. Now the machines are numbered 1, 2, 3, 4, 5, 6, 7, 8 as I indicate, consequently the machine which is now marked No. 5 was at that time marked No. 2.

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X-Q. 315. Now, cell No. 2 and cell No. 3 of that complete pyramid machine produced a finished concentrate?

A. They produced a rougher concentrate.

X-Q. 316. And cells No. 4, 5, 6 and 7, what do they produce?

A. They produce a middling product.

X-Q. 317. What became of the middling product?

A. The middling product was pumped back to cell No. 2.

X-Q. 318. And the rougher concentrate was pumped where?

A. To cell No. 1.

X-Q. 319. And from cell No. 1, then was delivered only finished concentrate?

A. Exactly so. The cleaner concentrates from cell No. 1 ran by gravity into cell No. 2. That is why we used cell No. 2, because we did not have to pump these cleaner tailings, because it ran by gravity into cell No. 2. That is the first cell handling original feed plus the middlings. The final tailings are made only by cell No. 7.

X-Q. 320. I think now we have it all. The only final tailings are made by cell No. 7?

A. Yes.

X-Q. 321. And the only final concentrates are made by cell No. 1?

A. Exactly so.

X-Q. 322. Your final concentrates from cell No. 1

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are assayed, and your assays are based on that concentrate as delivered?

A. Exactly so.

X-Q. 323. And the tailings also are from those tailings as delivered from machine No. 7?

A. From cell No. 7, yes sir.

X-Q. 324. And that applies to every one of these operations described in exhibit 163, is that correct?

A. That is correct.

X-Q. 325. When did you commence work at the flotation plant of the Butte & Superior Mining Company?

A. About the first of May or thereabouts; it was in May, 1913.

X-Q. 326. What kind of flotation machines were in use then?

A. The ordinary agitation and spitz box type, built entirely of wood.

X-Q. 327. Were they substantially the same as the standard mineral separation plants?

A. What is the standard mineral separation plants?

X-Q. 328. We have in evidence on pages 1030 and 1031 of the record in the Hyde suit, a drawing entitled "Complainant's Exhibit, King John's Court, Standard Plant." There is also on page 27 a cross section of that plant. Please look at those drawings and say whether or not they fairly in general represent the type of machine that was in use when you went to work for the Butte & Superior.

MR. KREMER: Do you refer to the record in this court or in the Circuit Court of Appeals?

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MR. WILLIAMS: To the record in this court, which is already in evidence.

A. No, I see quite a little difference to this which is represented here by the King John's Court Standard plant, and what was in use at that time at the Butte & Superior plant.

X-Q. 329. Are there any resemblances?

A. Yes, there is a resemblance, as there are spitz boxes and agitating cells in this drawing, and there were also spitz boxes and agitating cells in the plant of the Butte & Superior at that time.

X-Q. 330. And in addition <sup>in</sup> to the agitating cells was there a rotating agitator having blades located near the bottom of the cell?

A. There was.

X-Q. 331. And the pulp that was agitated in the agitating cell flowed into the spitzkasten?

A. It did.

X-Q. 332. And the froth from the spitzkasten overflowed? *A. It did*

X-Q. 333. And the tailings went where?

A. The tailings were elevated to the next agitating cell.

X-Q. 334. Where—Were these machines known by any name?

A. I knew of them by no name at that time.

X-Q. 335. You did not know them as the Hyde machines?

A. Absolutely not. I didn't know Hyde at that time.

X-Q. 336. Have you any drawing that you can pro-

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duce showing these machines as they were then installed?

A. I can make one for you.

X-Q. 337. Will you do that later on and let me have it?

A. All right.

X-Q. 338. I note that for the first quarter of 1913 the apparent recovery of zinc was 65.34 and that for the second quarter of 1913 that same item was 85.71. That appears on exhibit 158.

A. You are correct.

X-Q. 339. Can you explain why that great difference existed between the recoveries?

A. On April 25th the flotation plant was shut down for remodeling and changing over into a new system, which resulted in very much better recoveries after it was started up again—about a week or so later. You might say still that it might be due to the more oil being added; there was twice as much added during the second quarter as during the first quarter but I think it is due to the mechanical changes that were made which resulted in better operating conditions throughout in general.

MR. WILLIAMS: I will ask of counsel of the defendant whether they will produce a witness who is familiar with the operations during that first quarter, in view of the fact that they seem to have been most disastrous operations, and this witness can not tell anything about them except from the record.

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MR. SCOTT: We will furnish a witness, or two or three of them.

A. I was not present during that time.

X-Q. 340. Well, I won't ask you about it. Now, covering the period of your experience, when was the next shut down for alterations?

A. Well, the shut downs came pretty frequent about then.

X-Q. 341. Just run over them. Have you a record of them?

A. I have a partial record of them, and I find that during May of 1913 we did quite a lot of experimenting.

X-Q. 342. What did you do in May; how many times did you shut down?

A. Well, I haven't that all here; I cannot tell you that; but the conditions, the mechanical conditions were such that it was necessary to shut down quite often to fix up the plant. We changed in 1914 from the method of handling the material from one spitz to the agitating cell, and put in pumps instead of air lifts, and in the second quarter we changed and added more additional spitzkastens, which assisted in recovering, and later changed to pumps on No. 2 roughers, having changed on No. 1 before. Then during the third quarter and last quarter of 1914 the arrangement of the flow through the cells was changed, so that, instead of making five passes, as you might call them, or having five cells, we had seven. So then, in the last of 1914 we started to excavate for the new Janney machines, and

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during the first quarter of 1915 these Janney machines were being installed, one by one.

X-Q. 343. And that was the first installation of Janney machines at your plant?

A. Yes; and during the second and third quarter the Janney machines were completed, and the old machines were torn out.

X-Q. 344. Were those the pyramid Janney machines that you have now?

A. No. Now, then, again, those Janney machines were torn out and the pyramid type put in. That was due principally to the original Janney machines not operating well on account of the foundations. They were set upon concrete foundations, and the ground moved considerably up there, so that one machine was at an angle one way and the machine next to it was at an angle another way, and it was very nearly impossible to operate them; they had settled so much that they had to be entirely changed, and the pyramid was put in on wooden foundations, so that, if any more settling occurred, they could be brought back into shape again without having to tear up the whole plant and remodel.

X-Q. 345. When did you put in the pyramid machines that are now there?

A. We started putting in the pyramid machines during the latter part of 1916, was the first ones, and that was the No. 2, which is now the No. 5. That was the first one that went in, because we had no other machine in that particular part of our flotation plant at that

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time, and we could install that without interfering any with the operations of the other machines.

X-Q. 346. And then the other pyramid machines, when were they installed?

A. They were installed right along, following No. 2.

X-Q. 347. So that when did you have the complete pyramid plant installed and operating?

A. It was in February or March of 1917, I am not positive which, but I can give you the exact date by looking up the record.

X-Q. 348. Well, taking these records in Exhibit No. 158, do they enable you to fix the dates, or the time when the complete pyramid machine—pyramid plant was installed. You have divided it into periods.

A. Well, it was divided into periods on account of this report being kept up from time to time. This report was gotten out, and later on more material was added to it; that is, when we had a period of sufficient length of time to add to it. But it was not until some time in February or March that we started the entire plant, or that the entire plan was operating on the pyramid type machines. It was after we had started using 20 lbs. or more of oil per ton of ore on the entire plant.

X-Q. 349. Will you look up that date and let me have it?

A. I will.

X-Q. 350. What is the reason for dividing this report as to 1917 into periods?

A. Well, as I say, this report was gotten up in 1917,

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and was gotten up as far back as the first part of March, showing the results as they existed in this report at that time. Then, after the 20th, this report was gotten out, showing the same material, but for the additional <sup>90</sup> days in March, and the 21st to the 31st and the first to the 15th, which was not on the original report.

X-Q. 351. Taking the first period, December 22nd to January 7th, as to which you have supplied no details, why did you link that as a single period?

A. Up to that time we were operating the pyramid machines on more than 1% of oil and the rest of the plant on less than 1% of oil, and after that time the entire plant was started on more than 1% of oil.

X-Q. 352. Then during that period from December 22nd to January 7th you were operating a part of the plant on less than 1% of oil, but you do not include that in your report?

A. That is included in the third quarter of 1916. That is why the third quarter of 1916 is segregated from the average for the year 1916, on account of including from December 22nd to the 31st of December, when a part of the plant was in operation on more than 20 lbs.

X-Q. 353. Now, from January 1st to January 7th, the operations with less than 1% of oil are not included in the report, is that right?

A. They are not included.

X-Q. 354. When did you discontinue those operations with less than 1% of oil?

. A. We discontinued them on—January 9th was the

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first day that we operated the entire plant on more than 1%.

X-Q. 355. And from that time on were there any operations that were not shown in your report here?

A. There are no operations.

X-Q. 356. What happened between January 20th and February 3d, 1917; were they included in one period—I can't quite read that; was that the intention?

A. Yes, it was, but the exact amount of oil that was added during that period was 16 lbs., which is a little less than 20 lbs., and we had no oil analyses of the machine feed at that time, which consisted of the original ore and the circulating middlings in flotation.

X-Q. 357. Below that is that and the item, January 7th to February 6th, inclusive?

A. Yes.

X-Q. 358. Does that include a run?

A. No, that includes the entire period for that time.

X-Q. 359. Now that overlaps on February 4th to February 28th. Why are they overlapped?

A. Well, the correct oil analysis of the percent of oil in the ore and circulating middlings treated in flotation—we did not have it for that period entirely; that is the only reason that I know of why that is separated that way.

X-Q. 360. So that the overlapping in dates which appears in those two periods was an actual overlapping, but you took February 4th as the commencement of the period, because you had certain determinations for that period, is that right?

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A. Yes.

X-Q. 361. When did you commence to study the effect of larger quantities of oil than 1% in flotation concentration of ores?

A. I ran across that accidentally; I did not start to study that. That was in the summer of 1913, when I was sent to the Utah Copper to assist in determining what could be done down there with the flotation of their ores.

X-Q. 362. Did you perform any experiments in the San Francisco Court of Appeals at the hearing in the Hyde case?

A. I did.

X-Q. 363. What time was that?

A. I will have to look up the exact time on that.

MR. SCOTT: It was February, 1914.

X-Q. 364. It was February, 1914, I believe. And you say that you commenced to study the effects of larger quantities of oil at what time?

A. Well, as I said before, I was sent to Utah in July, 1913, and while down there I was endeavoring to see what could be done on the Utah Copper ore, and while investigating the possibilities of flotation at that time, as far as I knew of it, I found that in order to get results there, it was necessary to use quite a large quantity of coal tar or coal tar derivatives.

X-Q. 365. Now, you are talking about experiments, aren't you?

A. Oh, yes.

X-Q. 366. You performed experiments in this court

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on the hearing of the motion for a preliminary injunction, did you not?

A. I assisted in those experiments, yes.

X-Q. 367. And then you performed experiments at Wilmington, Delaware, at the trial of the Miami case, did you not?

A. I did.

X-Q. 368. And in the Supreme Court of the United States at the hearing of the Hyde case?

A. I did.

X-Q. 369. And in the hearing at Philadelphia in the appeal of the Miami case?

A. I did.

X-Q. 370. As I remember it, in the Miami case I asked you about how many experimental operations you had performed with large quantities of oil, and you gave me an estimate then of about a thousand; what is the present estimate?

A. Well, I don't know how I could estimate that. That is my general duty, to perform experiments and to investigate the possibilities of the various ores and oils, especially oils, and as there are many kinds of oils, why naturally the number of experiments that I have performed would run into a great number.

X-Q. 371. Now, you performed an experiment in court with a machine alleged to be the machine described in the Criley Everson publication. Is that the same machine that was used in Wilmington, Delaware, in the trial of the Miami case?

A. It is not the same machine.

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X-Q. 372. Is anything about it the same machine?

A. Substantially so, yes; it is similar to the one that was used there.

X-Q. 373. Well, is there anything about it the same machine?

A. No.

X-Q. 374. Is it a new machine?

A. It is not the same machine at all that was used there.

X-Q. 375. It is a new machine, and it is different from what the machine was there, is that right or is it the same in construction?

A. It is substantially the same in construction as the one that was used in the Miami case.

X-Q. 376. What differences have you made in the details of the construction in making this new Fryer Hill machine?

A. I have made no intentional differences whatever. There may be something slightly different in the construction, but it can not be the same machine, because the other machine is still in court.

THE COURT: You asked once about the Criley Everson and then about the Fryer Hill; are they both the same?

MR. WILLIAMS: I made a mistake. The Fryer Hill.

X-Q. 377. As you described this old Fryer Hill machine, you said the central tube was hollow, and there was an opening, I believe, at the bottom of the tube, just above the cross blade agitators?

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A. Yes.

X-Q. 378. What function did that hollow tube and that opening perform in the operation that was carried on in court?

A. It performed no function whatsoever.

X-Q. 379. As I look at it now, there are two holes at the place indicated, diametrically opposite, and they are both of them nearly stopped up; do you agree as to that?

A. I haven't looked at it; I will inspect it and see. Yes, they are partly stopped up.

X-Q. 380. When you rotated that cross blade agitator, in what manner did the inclined vanes on the bottom of that agitator operate, to throw the material outward or inward?

A. Outward.

X-Q. 381. You performed an experiment which concluded with an upcast separation of the metalliferous mineral, which sank against the upcast, and you said that roughly speaking the percentage of oil to metalliferous mineral was about 7%; is that right?

A. It is.

X-Q. 382. Can you give me the metalliferous mineral content of the ore that you used, having in mind that it contained not only blonde but some other metalliferous mineral?

A. Well, I would have to have that analyzed before I could give it to you. I only paid attention to the zinc content, and based my figures upon the actual zinc and zinc sulphide content. However, I will

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give it to you approximately from my own knowledge of how the ores run.

X-Q. 383. Well, you may give it approximately and correct it later if you are in error.

A. I will look it up and give it to you exactly.

X-Q. 384. Well, then, give it to me exactly. Does the insoluble, as given in the assay, give you a figure which, if subtracted from the total, will give as the difference the metalliferous mineral?

A. I gave no insoluble assay.

X-Q. 385. Well, is that so; that is, usually is that a fact?

A. It will give you very close to the amount of sulphide which is contained, which can be added to the amount of metal as determined.

X-Q. 386. You said that you were familiar with the Everson patent, and that you find in the Everson patent authority for the use of sulphuric acid and copper sulphate together?

A. I did.

X-Q. 387. Please point out in the Everson patent the part thereof which is authority for your statement about this, and read the part you refer to.

A. On page 1 of the Everson patent, line 87: "The acids which I have employed are sulphuric, hydrochloric, nitric, phosphoric, acetic, oxalic, tannic and gallic. I have also used the following salts, to-wit: the sulphates and chlorides of sodium, zinc and copper, and the double sulphate of potash and alumina." "The selection of the appropriate agents, will however, be

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largely determined in the practical working of my invention by the consideration of economy, which will obviously exclude the greater number of those above enumerated."

X-Q. 388. When did your knowledge of mining operations commence, or metallurgical operations?

A. Just what do you mean, a little more fully; I don't quite understand.

X-Q. 389. Well, when did you first commence to study or practice metallurgy?

A. In 1906.

X-Q. 390. While you were performing an alleged Fryer Hill experiment, I called your attention to the fact that the description of the ore in that experiment was as follows: "The ore was first crushed and rolled to such a degree of fineness as to enable it to pass through a forty mesh screen?" And then I asked you about the material that you were using in that experiment. Now, in the first place give me the screen analysis of that material?

A. I can't give you a screen analysis of that material, but I can give you a screen analysis of some of the same materials, of which I have made a screen analysis.

X-Q. 391. Which you believe will be substantially the same?

A. It will.

X-Q. 392. All right.

A. On a 65 mesh or plus 65 mesh, 2.21 per cent; +100 mesh, 8.03 per cent; +150 mesh, 9.24 per cent;

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+200 mesh, 19.48 per cent; ~~<~~200 mesh, 61.04 per cent. That is approximately what the other would be.

X-Q. 393. Did it go any finer than that?

A. I have nothing finer than 200 mesh.

X-Q. 394. Will you, as a metallurgist, stand for the proposition that this material that you used is a material such as was described in the Fryer Hill publication?

A. I will. My reason for doing so is that the Fryer Hill publications stated that that ore was crushed and rolled to pass a 40 mesh screen; and anyone familiar with the operation of rolling, crushing will know that in order to crush the ore equal to a 40 mesh screen that there will be a great proportion of fines made on account of the method of feeding the rollers, which will be a choke feed, and there will consequently be a great amount of fines made.

X-Q. 395. Now, have you the record of the daily operations at the commencement of your work with the Butte & Superior Copper Company?

A. I haven't the daily record tabulated as I have done in 1917.

X-Q. 396. But you have a daily record which will give the information?

A. Yes.

X-Q. 397. In what form is it?

A. Why, I have the daily record in report form; that is in daily reports which include the assays of the headings, the mill—the general tailings, concen-

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trates, flotation as produced by the mill and the amount of reagents used and the tonnage treated.

X-Q. 398. Well, will you let me see the record for the first months that you were there?

MR. WILLIAMS: While waiting I will hand up an affidavit of Mr. Ballot covering those matters in relation to the proposed supplemental bill of complaint which we were discussing.

A. It will be necessary for me to give you the date. The record for the first month I was there, I have got to go farther back than that because this report does not begin until the last of 1913.

X-Q. 399. MR. WILLIAMS: These are the earliest that you have?

A. Of this year. It will be necessary to go back and get the assay sheets, each individual one, and get the material from those.

X-Q. 400. Well, now, take the first day that you have a record of here?

A. All right.

X-Q. 401. What is that day?

A. November 1, 1913.

X-Q. 402. Now, this table that you have produced is the original record of the company, is it?

A. This one?

X-Q. 403. Yes, this table that you have here?

A. Yes.

X-Q. 404. That is the original record of the company and not a copy, it is a record of the company? Is that right?

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A. Yes, that is correct, yes.

X-Q. 405. And from it you have no tabulations wherein the days are brought together?

A. From it we have monthly statements, yes.

X-Q. 406. But no daily statements other than these?

A. Well, it don't include all the information that this does.

X-Q. 407. Well now, how many—what was the first item of that statement?

A. The first statement—the first item is ore received, dry tons for the day. The total to date, and the last of the month.

X-Q. 408. Well, for the day 1193 tons?

A. Yes.

X-Q. 409. And then what is the next heading or column giving tons, 1181?

A. That is the amount of ore that was milled for that particular day.

X-Q. 410. Now, give me the assay, of concentrates produced on that day?

A. The zinc concentrate produced, dry tons, was 377.

X-Q. 411. Now, give me the zinc content of these concentrates?

A. 50.5.

X-Q. 412. And the amount of the tailing?

A. The zinc content of the tailings?

X-Q. 413. No, the amount of the tailings?

A. Well, I would have to calculate that first.

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X-Q. 414. Well then, never mind. The zinc content of the tailings?

A. 3.1 zinc.

X-Q. 415. Now, that figure as the zinc concentrate, is that the zinc concentrate of the flotation plant or the total zinc concentrate of the mill?

A. Below here we have the zinc concentrate, zinc content of the concentrate that was produced by the mill, then also by the flotation plant separately by shifts.

X-Q. 416. Will you give me that mill zinc concentrate on the first shift that day?

A. That was 52.8; the second shift 53.0, and for the third shift 52.3. The flotation concentrate for the first shift was 49.7; for the second shift 49.~~8~~5 and for the third shift 49.6.

X-Q. 417. I notice a line giving the dilution of the flotation feed. I suppose that is the proportion of solids to water?

A. That is the proportion of the water to the solids, yes, sir.

X-Q. 418. Just give me that figure?

A. The first shift, 2.4; second shift 2.3; third shift 2.4.

X-Q. 419. Now, give me the amount of oil used, first, flotation oil pounds?

A. 1429 pounds the first day, which was equal to 1.209 pounds per ton.

X-Q. 420. And whose signature is signed to that sheet?

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A. F. R. Wicks, mill superintendent.

X-Q. 421. And that is the F. R. Wicks who has testified in this case, is it not?

A. That is the F. R. Wicks.

MR. GARRISON: I offer in evidence the following documents delivered by the defendant in response to our call, and ask that they each be admitted in evidence and marked with their appropriate number.

MR. KREMER: To each of the documents offered in evidence the defendant objects for the reason that it is incompetent, irrelevant and immaterial, and tends to prove no issue in the case and it is particularly incompetent insofar as the alleged issue of estoppel or res adjudicata is concerned in that no evidence has been introduced or offered which in its nature is of such a character as to constitute estoppel or res adjudicata as against this defendant; and for the further reason there is no sufficient issue of estoppel or res adjudicata raised by the pleadings.

THE COURT: These are part of the same matters to show payment?

MR. GARRISON: Yes, sir.

THE COURT: The same ruling. The objection will be overruled and exception will *be* ~~not~~ noted.

MR. KREMER: An exception should be noted to each of the exhibits.

WHEREUPON the following documents were admitted in evidence and marked with the respective exhibit numbers shown in connection with each.

Voucher No. 3409, amountng to \$165.00 issued to

J. M. Hyde under date of July, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 166.

Voucher of the Butte & Superior Copper Company No. 3495, amounting to \$155.00, in favor of J. M. Hyde, August, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 167.

Voucher No. 3508, amounting to \$150.00 issued to J. M. Hyde under date of September, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 168.

Voucher of Butte & Superior Copper Company No. 3519 amounting to \$150.00, in favor of J. M. Hyde, September, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 169.

Voucher of Butte & Superior Copper Company, No. 3584, amounting to \$150.00, in favor of J. M. Hyde, under date of September, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 170.

Voucher of Butte & Superior Copper Company, No. 3610, amounting to \$5,000, in favor of J. M. Hyde, October, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 171.

Voucher of Butte & Superior Copper Company, No. 3609, amounting to \$130.00, in favor of J. M. Hyde, October, 1911, admitted in evidence and marked DEFENDANT'S EXHIBIT 172.

Voucher of Butte & Superior Copper Company, No. 3764, amounting to \$230.15, in favor of James

M. Hyde, November, 1911, to which is attached a paper headed "Expense Account, Chicago Trip, J. M. Hyde," admitted in evidence and marked DEFENDANT'S EXHIBIT 173.

Voucher of Butte & Superior Copper Company, No. 4153, amounting to \$369.47, in favor of J. M. Hyde, March, 1912, admitted in evidence and marked DEFENDANT'S EXHIBIT 174.

Voucher of Butte & Superior Copper Company, No. 4154 amounting to \$400.00, in favor of J. M. Hyde, April, 1912, admitted in evidence and marked DEFENDANT'S EXHIBIT 175.

Check of Butte & Superior Copper Company, dated July 8, 1912, payable to the order of J. M. Hyde for \$200.00, to which is attached voucher of the Butte & Superior Copper Company, No. 4550 for the same amount and bearing the same date, admitted in evidence and marked DEFENDANT'S EXHIBIT 176.

Check of the Butte & Superior Copper Company under date of November 21, 1912, payable to James M. Hyde, for \$602.50, to which is attached two lead pencil memoranda and a letter on the letterhead of Hayden Stone & Company, Bankers, New York-Boston, bearing date New York, October 3, 1912, addressed to Mr. M. W. Atwater, Butte & Superior Copper Company, Butte, Montana, consisting of two pages, a typewritten sheet headed "Expense account of James M. Hyde, trip to Washington Patent Suit, leaving Butte, April 17th, 1912, amounting to \$334.05,

another typewritten document headed "Expense account of James M. Hyde, Trip to London, on Patent Suit, leaving Butte, July 18th, 1912," amounting to \$868.45, and voucher of the Butte & Superior Copper Company under date of November 21, 1912, payable to the order of James M. Hyde, No. 5333, amounting to \$602.50, admitted in evidence and marked DEFENDANT'S EXHIBIT No. 177.

Letter on the letterhead of the Butte & Superior Copper Company, under date of July 31st, 1913, addressed to Mr. J. L. Bruce, Manager Butte & Superior Copper Company, Limited, Butte, Montana, signed by N. B. MacKelvie, and a purported copy of letter bearing date Berkeley, California, July 30th, 1913, addressed to N. B. MacKelvie, signed James H. Hyde, admitted in evidence and marked DEFENDANT'S EXHIBIT 178.

WHEREUPON an adjournment was taken until 8:00 P. M. of this day, Monday, April 30th, 1917.

Prof. Arthur Fay Taggart.

8 o'clock p. m. April 30, 1917.

MR. SHERIDAN: If the court please, I think I would like to have Prof. Taggart give a resume of the fact which the pictures of the froths will show.

PROFESSOR TAGGART, recalled.

THE WITNESS: This is a drawing, similar, I think, to a drawing that was made the other day to show the situation of affairs at the surface of an air bubble in an oil contaminated pulp, containing sulphide mineral.

Q. Something like defendant's exhibit No. 128?

A. Yes. There is a bubble of air surrounded directly at the air-liquid contact with an oil rich layer, which grades in concentration from maximum oil concentration at the air-liquid surface to maximum water concentration removed away from the air-liquid contact. Then at the surface of the bubble, but not piercing the bubble <sup>so</sup> as to be in contact with the air, are the sulphide particles. Now, these for the photographs which we will show tonight will show some bubbles in that condition, with particles of sulphide sticking to the outside of the bubble. They will also show some of the bubbles that have emerged from the liquid and are found in the condition of air on one side of the bubble film, air in the other side of the bubble film, and the sulphide particles contained completely within the film, but at no place in contact with the air.

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Now, a proof of this particular contention, that the sulphide particles are at no place in contact with the air, is shown beautifully by some of the bubbles which are directly against the glass through which they were photographed in the froth. Those bubbles, in moving up along the glass, have been rubbed free of the sulphide particles by the mechanical moving along the glass, so that they present the appearance of those bubbles that the court saw this afternoon, that were not coated, which were in contact with the glass. Those bubbles may, however, be coated at other places where they are not in contact with the glass. Now, that means, that if you look through this side of the bubble it is clear along the glass, and as the photographs were taken the camera was at a point such as this (indicating) and the light was coming from a point such as this (indicating) and from those clear bubbles there will be noticed two reflections of that light, one from this surface of the bubbles and one from this surface. I think that can be illustrated rather well by looking at the reflection of light, here with this water bottle; there are two reflections of that light, one from the concave surface and one from the convex surface. Now, we will get exactly the same condition in some of the bubbles that are clear in contact with the glass in the photograph which you will see. The fact that we get those two reflection is a proof of the fact that there are no sulphide particles on the back of that bubble, sticking through into contact with the air, because if there were particles on

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the back of the bubble sticking through into contact with the air, then the back of the bubble would be dull, and would be a non-reflecting surface. I think I can show it with a rough diagram. If this represents a smooth reflecting surface and this is the source of light, and the eye is here, the gleam of that light will be recognized by the eye from this particular angle, and the angle which the beam of light makes with the plane, that is the angle A, will be equal to the angle at which the light goes to the eye; in other words, the angle of instance of the light is equal to the angle of reflection. Now, if we take a surface rough and corrugated in that fashion, the beam of light will go in the same way, but no beam of light will be recognized by the eye at this point; there will just be a general illumination, due to the diffusion on the rough surface. If the back surface of the bubble in the pulp were in this condition, as it would have to be if the bubble stuck through into contact with the air, then there would be no second reflection from the back of the bubble, but merely the one reflection from the front of the bubble that is clear and in contact with the glass.

I have represented here the rays of light as they will be reflected from the outer surface of the bubble and the rays of light as they will be reflected from the inner surface of the bubble to the eye. I think that is all, as far as that particular phase is concerned.

PROF. TAGGART: Now, the pictures will also

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show that it is impossible, by visual examination, to tell whether a froth has been made with more or less than one per cent of oil; and that will further show, as more or less of an incidental feature, that it is possible by the eye to tell and distinguish in froths—in some froths at least—provided these froths have been made with different oils, but with the same oil less than one per cent of oil and more than one per cent oil, is impossible to tell from the photograph.

MR. WILLIAMS: These sketches should be marked as exhibits?

MR. SHERIDAN: I will introduce them now.

This first sketch referred to by Prof. Taggart, his diagram No. 22, we offer in evidence.

Diagram Taggart's No. 22, admitted in evidence and marked DEFENDANT'S EXHIBIT 179.

MR. SHERIDAN: And then the second one will be offered.

Taggart diagram No. 23 admitted in evidence and marked DEFENDANT'S EXHIBIT 180.

MR. SHERIDAN: Q. When the pictures are put on the screen first, Mr. Phillips will give us an idea of about how large the magnifications will be on the screen, how large the increase in diameter will be of the lantern slide, and then the relative size of the magnification upon the screen.

MR. PHILLIPS: Some of the photographs were

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magnified—one series of photographs were taken natural size and in making the lantern slides from those photographs they are reduced on the lantern slides and the photograph of the top of the film which are natural size, the slides are reduced to 7-11 diameter, 7-11 of one diameter. The photographs that are magnified five diameters on the lantern slide are reduced to 2 3-10 diameters; and the photographs that were magnified 15 diameters are reduced to 6.9 diameters—that is on the slides. Now, in projecting these slides, the picture on the slide is two inches wide, and we make the image of the slide and thus magnify the picture on the screen in inches, divide that by two; the width of the image in this case is three feet. That will be 36 inches. Divide that by two and then the magnification by the projection is 18 diameters and multiply the 18 diameters by the magnification on the slide in whatever case it will be and that will give the diameters of the magnification of the image, and then by squaring these diameters it will give you the number of times that the picture is magnified. The pictures of the top view are magnified on the screen under these conditions 120 times, that means about eleven diameters. The series of pictures marked No. 2, that is the photographs magnified five times are magnified on the screen 1700 times, a diameter of about 41. And the fifteen magnifications are magnified on the screen 17,000 times, 1302 diameters. Now there are a number of slides of bubbles and the bubbles are of different di-

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mensions and different magnifications, and that large magnification will be 37<sup>5</sup>,000 times on the screen, and the first five slides of bubbles will be magnified 64,000 and the other one will be magnified 72,000 times.

MR. WILLIAMS: Will you just go into detail a little about these magnifications?

MR. PHILLIPS: "Diameters" is lineal measure, and then the number of times magnification represents the area or square. You square the diameter to get the times.

MR. SHERIDAN: Q. Mr. Phillips, will you please tell us when a picture is thrown on the screen the particular oils that were used and the thickness of the froth? The first number indicate the index of the particular picture; the second number, say 1, 2, 3, as to whether it is the top view of the side or the magnified five diameters or the side one magnified fifteen diameters. They are repetition, these slides are replicas of the pictures that were put in evidence but we want to put the slides in evidence so they can be shown to the court more thoroughly.

MR. PHILLIPS: That is froth from oil mixture No. 3, and the froth was a quarter of an inch thick.

MR. SHERIDAN: Professor Taggart will make a technical—any technical explanation he sees fit on each picture as put on the screen.

PROF. TAGGART: I would like to have the court notice here chiefly that these bubbles are very similar in appearance to those that we saw through the microscope the other day. These represent bubbles which have air here on the upper side, the atmos-

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phere, and upon the inner side some of the air that was beat into the pulp and has risen with this and other bubbles which have combined to form the big bubble, but the particles of mineral are within the film itself. The film raises smoothly and regularly over the particles; there are no jagged projections which would be characteristic of a mineral particle sticking through into the air. There you notice also that the froth is rather sparse in that particular particle. This represents the same froth magnified five times. The upper line of the froth comes along in about here (indicating).

MR. PHILLIPS: 120 times that is.

PROF. TAGGART: I think that is all of that.

MR. SHERIDAN: I wish you would put that screen back again. I would like to have Prof Taggart direct the court's attention to the hanging particles at the lower part of the froth.

MR. TAGGART: Yes. These are the particles. Of course on these froths that are made in the machine where the froth is not removed as rapidly as it is made, that represents the overloaded bubbles which gradually become so heavily laden that the buoyancy of the air within the mass of bubbles is not sufficient to buoy up the particles. Such a condition is not characteristic of froths that are being removed continually, and is a characteristic in the small machines where the mineral—where there is plenty of mineral present with small quantities of oil as it is with large quantities.

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MR. WILLIAMS: What is the percentage of oil in that froth?

MR. TAGGART: The percentage is one tenth of one per cent, isn't it, Mr. Phillips?

MR. PHILLIPS: Yes.

MR. KREMER: The upper part of this shows the film on the glass.

MR. TAGGART: Oh, yes, just the contamination and dirt, and that will be observed on all of these froths that represent a magnification of five diameters. That is the upper line of the film. We get this in all cases above the top of the froth, a contamination on the glass which can be distinguished from the froth.

Now, you will notice here in this particular slide which is a projection magnified some thirteen hundred diameters the small particles plastered all over the outside of the bubbles. This mass through here represents similar bubbles of—similar bubbles very heavily coated with the solid particle. You see here these bubbles are under the water so that you are looking from the water side, from the pulp, as it were, against the bubbles, and consequently looking directly at the solid particles themselves. Now, as these rise to the surface and come out into the atmosphere, then the film has air on both sides and these particles are then wholly within the film.

MR. PHILLIPS: That is oil mixture No. 3, 0.3 per cent.

MR. TAGGART: This is 0.3 per cent; the former

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was 0.1 per cent. You will notice that there are more bubbles, the whole surface of the jar is covered in this case with bubbles. The bubbles are larger and characteristic of the froth that are obtained from the later cells of the flotation machine as they are operated in the mill, that is the solid, while the mineral has become impoverished, and the pulp has become impoverished of some of its oil. This represents the same froth magnified in the picture some 41 diameters. You will note here the presence of an enormous number of small particles. These are plastered on the outside of the bubbles and some of the bubbles can be seen in a very rough fashion here. The characteristic appearance of the bottom of the film—of a film made in one of these square glass jar machines is noticeable here, and it will be noticed a dropping is shown about the same as it was in the froth made with the smaller quantity of oil.

Here is some froth magnified 130 diameters. Now, here you will notice the reflection that I speak of, here and here and here, where these bubbles which have been or are in direct contact with the glass walls of the cell, and they have been rubbed free of the load of solids that was on that particular surface, and the material has been distributed around here. It will be a little more noticeable, the particular distribution of the load of mineral on some of the other bubbles, but you will notice here is one of the reflections from one of the surfaces of the bubble, and here is the reflection of the other surface of the bubble.

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Here are the two spots of light, and here and here, and in all these it will be found that you have two spots of light, one reflected from the smooth outer surface of the bubble and one reflected from the smooth inner surface of the bubble.

MR. PHILLIPS: That is .4 of 1% oil mixture.

MR. TAGGART: Now, this froth is considerably heavier than the preceding ones. Your honor will notice the drawing back of the bubble film where the bubbles are broken here and here, the extremely viscous condition of that film, due to the intrusion of the solid matter. I think your honor noticed that in one of the froths this afternoon. The characteristic appearance of these surface bubbles is again apparent here. There is absolutely no sign here of a particle projecting from the bubble film, the films in that case rising smoothly from the particles, and the same is true, as was shown under the microscope of the other side of the film; that is, under the microscope the two sides of that film were absolutely indistinguishable. It was a type, and it showed the surface in contact with the air, and there is air of course inside of this bubble. Now these bubbles in the side view have but one side in contact with the air, and the side that we see is the side that is in contact with the water, and consequently there the particles are not included within the film, because the film as a film is not yet formed, but merely that the oil rich layer at the air-liquid contact with solid particles held in that oil rich layer and being brought to the

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top. As soon as they emerge into the top then they are entirely inclosed.

Here is a magnification of some 41 diameters of the same froth. You will notice here the bubble outlines, and see again this still characteristic fringe at the bottom.

Here is the enlarged view of these bubbles in contact with the glass, showing the two spots, the reflection from the outer and the inner surface.

MR. PHILLIPS: One half of one per cent. oil mixture.

MR. TAGGART: This is the same oil only a greater amount, and on the surface of course it is possible to distinguish the froth produced by one-tenth or two-tenths or three-tenths of 1% from the froth produced from oil five-tenths of 1%, because in the lower quantities the froths are so starved with the small quantity of oil that they did not completely cover the surface, but from now on the froths will be sufficiently voluminous to completely cover the surface of the jar, and from now on it is absolutely impossible to distinguish between them. You will notice here again this viscous film to which your attention was called in the last picture, and again the particles are wholly within the film.

This is a magnification 41 times, again with its characteristic fringe at the bottom.

Here the magnification is 130 times with the bubbles showing generally in contact with the glass, clear and showing two spots. Now you will notice upon

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this bubble that some of the solid matter has been rubbed off of the surface and that is seen on the bubble at the point where it is in contact with the glass, and of course this solid matter extends all around the surface of the bubble, except this small point or area that is in contact with the glass.

MR. PHILLIPS: 0.6 of 1% oil mixture.

MR. TAGGART: Here is the same oil, slightly more of it, and the same characteristic appearance absolutely.

This is a side view, looking through the glass, 41 diameters. The outline of the bubble here, and the fringe again at the bottom.

Here is a larger magnification.

MR. PHILLIPS: This is 1% of oil mixture.

MR. TAGGART: I don't think that there is anything peculiar about this to comment on; I have been saying the same thing over and over again about these as we went along. This is 41 diameters.

This is 130 diameters.

MR. PHILLIPS: 1 $\frac{1}{4}$ % of mixture.

MR. SHERIDAN: Q. Point out those viscous films again.

A. Here are the bubbles which have broken this way, and have drawn back. The persistence of course of these films as a sort of sheet is a sign of their high viscosity.

Here is the same film magnified 41 diameters. Here again, magnified 130.

Q. You see some of those birdseye bubbles there?

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A. I see the spots in here just the same.

MR. PHILLIPS: This is  $1\frac{1}{2}\%$  of oil mixture.

MR. TAGGART: Here again the film is so like those that were shown before that it is useless to point out the particular characteristics.

This is a magnification 41 diameters. You notice that the fringe at the bottom is no more pronounced than it was on the lower quantities of oil.

Here is the high magnification with these characteristic bubbles showing the reflection from the front and the back surface.

MR. PHILLIPS: This is one-tenth of one per cent. eucalyptus oil.

MR. TAGGART: There you can see a decided difference from the one-tenth of one per cent. of this so called oil mixture. You will remember that in the one-tenth of one per cent oil mixture there were bubbles around covering the surface with the exception of an area which would be included about where my pointer has passed. Here the bubbles are so scarce that the surface presents the appearance merely of a broken scum as it were, on the surface. These dark spots represent where bubbles have broken, and the surface is not covered with solid matter; in other words, you can see the water at those points.

MR. WILLIAMS: It should be noted here on the record that this froth was produced with California eucalyptus oil, which has never been used in the flotation process, and it was not made with the Australian eucalyptus oil which has accomplished such wonderful results.

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MR. TAGGART: This is the side view of that particular froth of which we just had the top. Here you can see that there was a slight froth which was apparent at the surface.

MR. WILLIAMS: Do you know where the line of that froth ends?

THE WITNESS: About here.

MR. SHERIDAN: Just above the bubbles?

A. Yes.

Q. How is the characteristic fringe, pronounced or not?

A. It is rather pronounced.

Here is the same froth magnified to the high diameter.

MR. PHILLIPS: This is five-tenths of one per cent. California eucalyptus oil.

MR. TAGGART: Your honor will notice here a very decided difference between this particular froth and the froth that was formed with the five-tenths of one per cent oil mixture; in other words, it is quite easy, not to say the particular oil with which a froth was made, but with many froths, to tell that they were made with different oils. However, given the same oil and varying, not the conditions but the quantity, then the problem of distinguishing the froth is an impossible one, visually.

Here is the magnification 41 diameters of the froth which has just been shown. The upper line of the froth runs through in some such position as this; I think it probably runs up a little like this, ~~with this~~, with this bubble rather up in the corner.

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Here again we have the characteristic two spots reflected from the bubbles whose surfaces are in contact with the glass or film.

MR. PHILLIPS: This is 2% eucalyptus oil, and the mineral in this case is chalcopyrite and silica. This is a side view, 41 diameters.

MR. TAGGART: We do not have the top of that froth?

MR. PHILLIPS: No.

MR. TAGGART: There is an apparent difference in that froth from the others that we have seen, due, evidently to the different mineral and to the great quantity of mineral in the froth. There is some froth there which shows the bubbles in contact with the glass, but they have not been sufficiently agitated, or they are too heavily loaded with the particles to rub them clean, so that we do not get the reflected surfaces as before. The white dots in these bubbles represent the reflection from the surface of the sulphide minerals. You will notice that the type of the reflection here is very different. On the other bubbles the reflection unquestionably was not mineral, because mineral does not distribute itself in this fashion on the bubbles. Here the promiscuous distribution of the mineral on the bubbles is not a similar case at all.

MR. PHILLIPS: This charge was made up according to the California Journal of Technology, mechanically mixed.

MR. TAGGART: Here again we have an obviously different appearing froth from either of the two pre-

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vious froths, the difference being due, however, to the fact that different ingredients were used in forming the froth, not that different percentages of oil were used.

There is the side view of the same froth, magnified 41 diameters.

Here is the highly magnified view, 130 diameters.

MR. PHILLIPS: This was the same charge, only it was mixed by hand in a mixing bottle.

Q. BY MR. SHERIDAN: Just as it was on the judge's desk?

MR. PHILLIPS: Yes.

MR. TAGGART: The white streak down here is a reflection from the rounded surface of the bottle. The other photograph was taken in a square jar.

This is the same highly magnified, 130 diameters.

MR. PHILLIPS: These are bubbles of one-tenth of one per cent. eucalyptus oil.

MR. TAGGART: These are very much more magnified than any of the previous ones, are they not?

MR. PHILLIPS: They are magnified 64,000 times, 252 diameters.

MR. TAGGART: These were made by taking some of the froth from the machine and placing it in a small tube about one-eighth of an inch inside diameter, and then filling the tube up with water and corking both ends, so that the bubbles were completely immersed in water, and the tube was laid on its side and photographed. You will notice here even more distinctly than in the other photograph, the rough appear-

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ance of the outside of this bubble. These are the solid particles stuck onto the outside of the bubble, inclosed within the oil rich adsorption film at the air-liquid contact surface.

MR. WILLIAMS: What is that bubble at the upper right hand corner?

MR. TAGGART: Perhaps Mr. Phillips can tell us if he recollects the particular appearance of that. He probably does not. You see these are magnified 250 times, Mr. *Phillips*.

MR. WILLIAMS: 252 times.

MR. TAGGART: So you don't notice a particular spot one-two hundred and fiftieth of that size?

MR. PHILLIPS: That is a bubble with no mineral, water on that face, directly in contact with the glass.

MR. WILLIAMS: Were those bubbles up against a glass surface?

MR. PHILLIPS: Yes, they were.

MR. WILLIAMS: So that they are a little bit flattened?

MR. PHILLIPS: Not very much; they probably are a little flattened.

MR. TAGGART: They were against a round surface; they are contained in a glass tube about one-eighth of an inch inside diameter.

MR. SHERIDAN: In that upper right hand corner are those the characteristic two high lights?

A. They look like it, but I would not care to say.

MR. PHILLIPS: No, they are not.

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MR. WILLIAMS: I think I can see about four, myself.

MR. TAGGART: I think so; I would not want to say about those; I think there are several.

MR. WILLIAMS: What is that in the upper left hand big bubble, that dark space in the middle with spots in it?

MR. TAGGART: I think very likely that is the place at which the bubble is in contact with the glass, and the solid has been abraded away at that point. I looked at some of those bubbles under the microscope, but not quite as high a magnification this morning, and that is quite a characteristic appearance, as this is also, where that particular bubble has been bumped at that particular place, and the mineral has been moved over and moved back here.

MR. PHILLIPS: These are bubbles taken from a charge containing one-half of one per cent. eucalyptus oil.

MR. TAGGART: And the previous one was how much?

MR. PHILLIPS: One tenth of one per cent. These are the same magnification.

MR. PHILLIPS: These are the same magnifications.

MR. TAGGART: Note the difference in the appearance of these bubbles.

MR. PHILLIPS: These are bubbles taken from a charge containing 0.1 per cent of mixture No. 3 magnified the same, 250 diameters.

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These are bubbles taken from a charge containing 0.5 per cent oil mixture No. 3, 250 diameters magnified.

PROF. TAGGART: You will notice the characteristic two spots in these various bubbles, that are observable.

MR. WILLIAMS: Those are air bubbles, aren't they?

PROF. TAGGART: They are not completely clear, Mr. Williams, but there isn't a particularly heavy load on them.

MR. PHILLIPS: They are air bubbles separated from the water in part.

MR. WILLIAMS: To my mind they are clear bubbles, showing similar reflected surfaces.

PROF. TAGGART: Similar reflected surfaces, certainly, to those that we had before.

MR. WILLIAMS: They have no metal in them?

MR. TAGGART: Some of them have. I noticed this morning in this examination that I spoke of that those particles are very lightly loaded—this is, most of them. I could not say all because I was not looking to see whether all of them bore a load, but most of these bore a light load of mineral. Of course it was not nearly so heavy a load as was borne by the big particles.

MR. PHILLIPS: That is a mixture containing one and one half per cent of oil mixture, magnified 250 diameters.

MR. TAGGART: And the previous one was how much?

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MR. PHILLIPS: 0.5 per cent.

MR. TAGGART: I would like your honor to look closely at this and then we will go back to the previous one, for this one is 0.5 per cent above the line and the other 0.5 per cent below. Except as a matter of different illumination it seems hard to note any distinction between the two slides.

MR. PHILLIPS: This is the same mixture, same kind of bubble, 1.5 per cent of oil mixture.

MR. SHERIDAN: Enlarged how many times?

A. 64,000.

MR. WILLIAMS: 64,000.

A. 252, as before.

MR. WILLIAMS: 250 diameters.

MR. PHILLIPS: 250 diameters. This is a bubble from a charge containing two per cent of eucalyptus oil and the magnification is 612 diameters or 375 thousands.

MR. TAGGART: And a different mineral is used there.

MR. PHILLIPS: And the mineral is chalcopyrite and silica.

MR. TAGGART: I think the difference here in the appearance of the bubbles is largely a question of the mineral.

MR. PHILLIPS: I would like to state that that bubble is interesting. In fact, in putting this bubble in and putting the cork on top, they put too much pressure and they condensed the air bubble and the coating of the bubble was ruptured and it was so well formed that it very nearly retained its shape.

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This bubble is from a charge containing two per cent eucalyptus oil, the same mineral, chalco-pyrite and silica and magnified 270 diameters or 72,000.

This was wood tar oil 0.1 per cent, Butte & Superior ore.

MR. TAGGART: Here again you see these characteristic two spots on these bubbles in contact with the side of the cell, it being borne in mind that these are photographed under water.

MR. PHILLIPS: That is wood tar oil 0.3 per cent.

MR. SHERIDAN: What ore?

MR. PHILLIPS: Butte & Superior ore.

MR. TAGGART: And note that the froth is very sparse. The <sup>ar</sup> represents about the upper line of the froth on this particular picture. The part above is the dirt on the sides of the cell. Here we have the higher magnification with the same froth.

MR. PHILLIPS: This is 0.3 per cent wood tar oil, Butte & Superior ore.

MR. TAGGART: Again the surface of the froth shows very clearly the characteristic bubbles. The flattened effect between the—The flat effect, although the complete surface of the jar is covered. There again we have a thin froth.

MR. SHERIDAN: Side view.

MR. TAGGART: This is the side view, 41 diameters, the upper line of the froth runs across about here.

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MR. WILLIAMS: Isn't that a case of very small bubbles, as the enlargement would bring it out?

A. We will be able to see on the next bubble. The bubble appears to be about the same size as in many of the previous ones.

MR. WILLIAMS: I see a bubble there with four reflections on it.

MR. TAGGART: Yes, I have an idea that there are two bubbles there.

MR. WILLIAMS: <sup>Phillips</sup> 0.4 per cent pine tar oil, Butte & Superior ore.

MR. TAGGART: Here again we have this characteristic froth. The froth is in contact with the air particles wholly included within the whole surface froth.

MR. PHILLIPS: This is the 41 diameters.

MR. TAGGART: It is characteristic—you see it is characteristic of that oil that the bubbles were considerably larger than on the other oils used, do you not.

MR. PHILLIPS: Very much larger.

MR. TAGGART: The upper line of the froth is about here.

Here we have the 70 magnification and the bubbles are sufficiently heavily coated and sufficiently tough so that the cell matter has not rounded off in contact with the glass.

MR. WILLIAMS: As I read that those are separate bubbles, with the dark lines between them?

MR. TAGGART: Yes, sir. We will see two, five.

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six, rather large and one rather small bubble complete the main point of that particular film.

MR. WILLIAMS: I think that that particular picture shows how, when bubbles are crowded against each other, the adjacent walls flatten out to almost planes. I think that shows that very well, when they are crowded together in the froth.

MR. TAGGART: I should most certainly expect some flattening, yes, sir.

MR. PHILLIPS: This was 0.5 per cent pine tar oil. That same thing is shown clearly here. This is the top view, but the junction is practically straight lines. This is a characteristic of any substance closely packed.

Here is the same froth, side view, magnified 41 diameters, showing one of two clear spots here where the film has been rubbed off one side by the contact with the glass and here is the same froth magnified 170 diameters showing approximately the characteristics of the previous one.

MR. PHILLIPS: 0.6 per cent pine tar oil.

MR. TAGGART: There is no difference in this top view to comment on. The top of the froth in this particular view is about in there.

MR. SHERIDAN: Side view?

MR. TAGGART: This is a side view magnified 41 diameters. Here again it is similar to the previous one and here is the side view magnified 170 diameters. I do not think that needs comment except for similarity.

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MR. PHILLIPS: This is one per cent pine tar oil.

MR. TAGGART: Again you note we have the characteristic bubble, too.

MR. SHERIDAN: Right there, near the lower left hand corner we see a kind of small raised point and one large bubble. What is that?

MR. TAGGART: I have an idea, Mr. Sheridan, that that is a smaller bubble. I do not think there is a larger particle being held there. The small bubbles will sometimes appear on the surface of the larger ones and give that same appearance. I think, however, that up here at the upper left-hand corner, a little just to the left, there are particles included within the film. It is rather easier to tell that under the microscope, where you can see whether the particular protuberance has a small particle within or ore in air, but I think that this one is too large for a small particle.

Here is the side view magnified 41 diameters of the same film. This I think you said was one per cent?

MR. PHILLIPS: One per cent.

MR. TAGGART: The top of the froth being about along here and the froth being sufficiently light, there is no need to call attention to that. Here again you see the same froth magnified 170 diameters.

MR. PHILLIPS: 30. One—~~1.5~~ per cent pine tar oil.

MR. TAGGART: This again is evidently similar to the previous froth. The side view magnified 15 diameters with the top of the froth coming in to about here. And here the froth is again magnified 170

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diameters. The bubbles are heavily laden with solid material.

MR. PHILLIPS: Two per cent pine tar oil, Butte & Superior ore used on all of these tests, these pine tar tests.

MR. TAGGART: You will notice here this characteristic leathery appearance of the things, and here is one of the bubbles broken and with rather viscous film between as seen in the photograph; and a side view of the same froth magnified 41 diameters; the top of the froth running into about through here.

THE COURT: Why do the bubbles seem so much more towards the bottom than towards the top? They are not so distinct.

A. Some of these bubbles are drawn up along the sides. You know that the froth is higher on the sides than in the center and you get the contact then of that upper bubble with the one directly under it, which outlines this particular contact. The dark spaces above here represent the spaces below which the tops of the top bubbles lie, and the line here represents the point above which, and I have drawing my pointer at some point in through these two as representing approximately the top.

Here is the same froth magnified 170 diameters with a characteristic appearance of the preceding ones.

MR. PHILLIPS: We have no good night slide, but I think that is the last one.

MR. SHERIDAN: I would like, if your honor

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please, to offer this box of lantern slides in evidence, *en bloc*, as defendant's exhibit 181, and I would like to do this with them if Mr. Williams will agree, and that is I would like to have them remain in our possession with a right to call for them at any time.

MR. WILLIAMS: Yes, I think that would be more convenient for each party showing films ~~or~~ pictures of this kind.

THE COURT: The record will so show. I suppose that completes it.

The slides admitted in evidence and marked  
DEFENDANT'S EXHIBIT 181.

WHEREUPON an adjournment was taken until 10:00 a. m., Tuesday, May 1st, 1917.

Tuesday, May 1st, 1917, 10 o'clock a. m.

THE COURT: In the matter of the application to file the supplemental and amended bill, which is also a bill in intervention, but of course it is not the labels on the bill which control, it is the substance of the bill; and even though they may not have placed upon the bill all the labels it ought to bear, it is no objection to its being filed.

This amendment proposes to bring in other parties in intervention; they themselves are here, asking, in

that they have a right as licensees of this patent to share in the proceeds of the action, insofar as there is a recovery for infringement at all. It seems to be and it ought to be the practice in patent suits to join the patentee and his licensees, in that it makes for singleness of action and prevents multiplicity of action.

As a matter of fact, if defendant knew that this patent right had been in fact assigned to licensees, and failed to make it known, and had allowed the patentees to secure a full recovery, they would still be liable to the licensees for what was properly theirs; the same as in the case of the assignment of a cause of action; if the debtor does not insist upon the assignee, if the suit is by the assignor, being brought in, and lets the assignor recover, the debtor is still subject to the claim of the assignee, so that it is really for the benefit of the defendant in this suit that these parties should be brought in. At the same time the court, knowing this, of its own motion would insist upon it, because certainly this court does not want to try this case or any part of it again, and it would be obliged to if these licensees were not here.

Now, the other feature of the proposed amendment enlarged upon the fact that the Hyde case had been decided, the decree and mandate. As the court stated the other day, as far as it is for the purpose of pleading *res adjudicata*, it is really anticipating the defense, that that too has been customary in patent suits. I notice in a Supreme Court decision a few days ago, and I failed to make the notation, though it is within the last 50 volumes, which makes it very definite to you of

course—the Supreme Court casually observed that former adjudication should be either pleaded or introduced in evidence, without commenting on the practice. The patentee, no more than anyone else, is bound to anticipate a defense. They could introduce it in evidence without pleading it. In this case when the former adjudication, by name at least, is against a party not party to this suit, fairness to the defendant requires that it should be pleaded, but it could ordinarily be introduced in evidence after the defense of invalidity is made, no replication being necessary. That is only the general law of practice and pleading.

Now, as to lack of diligence, the condition in respect to that is the same as it was when the defendant a few days ago asked leave to amend their defense and introduce new patents and the California publication. The court said there that the peculiar circumstances of this case would serve to render the delay, not lack of diligence, because both parties were resting quiescent in a large measure, waiting for the decision of the Hyde suit. So here, as far as there not been diligence in bringing forward these assignees or licensees, the court does not think the objection is well taken, for, as I said before, the court would order them in; intervention may be had at any time prior to the conclusion of the suit, as long as it does not operate to the prejudice of the defendant, and it does not in this case. None of this new matter in the supplemental bill is any surprise to the defendant, and so the amendment, or the supplemental and amended bill and bill in intervention will be allowed to be filed.

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MR. KREMER: Your honor will allow us an exception?

THE COURT: Exception will be noted.

MR. KREMER: And will your honor make a further order providing in what time we shall answer?

THE COURT: What time would you like, five days?

MR. KREMER: Ten days; I think we will be here that long, surely.

THE COURT: You are to conclude your case this week, as I understand it, and you ought to answer before you conclude. I will give you until Saturday morning. There is nothing new in this, really.

MR. KREMER: No, it is merely the preparation of the answer, the mechanical part of it. The answer will be in form the same as the one now.

THE COURT: Saturday morning.

BEN H. DOSENBACH resumed the stand for further

#### CROSS-EXAMINATION.

X-Q. 422. To complete the record of November 1, 1913, what oils were used on that day?

THE COURT: Now you are inquiring with respect to what? Your question relates to a former one, but that former has passed out of the court's mind.

MR. WILLIAMS: I was inquiring about the operations of the plant on November 1, 1913, that being

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the earliest day of which he had any record with him and I am completing that record now?

A. The oil used on November 1, 1913, was 1.29 pounds pine oil per ton.

X-Q. 423. Was heat used on that day?

A. Heat was used on that day.

X-Q. 424. Was sulphuric acid used on that day?

A. Sulphuric acid was used on that day.

X-Q. 425. I don't think I obtained from you the tonnage of the feed to the flotation plant on that day?

A. The tonnage was 1181 tons to the mill on that day; and until such time as I can segregate that part of the concentrate which was made in the concentrator from that which was made in the flotation plant, I cannot determine exactly what the feed to the flotation plant would be on that date. This is the total amount of zinc concentrate for this day and it does not show the tonnage of lead; that is plus the mill feed, independent of the flotation plant.

X-Q. 426. What would be your method of calculation?

A. My method of calculation would be the tonnage of the lead concentrate plus the tonnage of the zinc concentrate produced in the wet concentration portion of the mill subtracted from the mill heads or tonnage to the mill; that would give the total amount of ore to the flotation plant.

X-Q. 427. That is to say all the material except the concentrate taken out by wet concentration goes into the flotation mill?

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A. That is so.

X-Q. 428. And is this method of calculation the method that has been used throughout?

A. It is.

X-Q. 429. There has been no different measurement taken of the dry feed to the flotation plant?

A. We have no definite method other than the calculating method, by deducting the products that are taken out before the feed comes to the flotation plant.

X-Q. 430. Now, have you the record for September 13th?

A. September 13th—as to what, Mr. Williams?

X-Q. 431. Have you here the monthly summary and averages for September, 1913?

A. Yes, I have the tons milled and I have the power and the oil and acid and I can give the assays for September, 1913.

X-Q. 432. Individual assays for the different days' runs?

A. Some I haven't got them segregated it has been impossible for me to get all the material together from that. Any particular day that you might want I can give those days and give you all the information on those days. There is quite a voluminous record to go through.

X-Q. 433. Well, I would like to have a daily itemized statement for some time in September?

A. 1913?

X-Q. 434. 1913, which would approximately give the day on which the concentrates were made that were

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found on a car in Oklahoma on September 18th, 1913, making allowance for the usual delay in transportation?

A. I don't know how I can get that.

X-Q. 435. Somewhere about that time. I presume that you didn't make any great changes then and you can take some day which in your judgment would be about the time that these concentrates were made, and let me have that day and the days thereabouts. You have got that record, but you haven't it here with you?

A. No. Maybe anywhere from one to three months or nine months before that; maybe less and maybe more.

X-Q. 436. Bring the daily record of that time and we will probably be able to get something that will be of assistance. Tell me, however, what oils you were using in September, 1913?

A. We were using pine oil and some oleic acid.

X-Q. 437. Pine oil and what?

A. Some oleic acid.

X-Q. 438. And what general proportions of pine oil to oleic acid?

A. Approximately I should say fifty of each.

X-Q. 439. And the total oil was how much to the ton or what percentage of the feed?

A. In September, 1913?

X-Q. 440. In September, 1913?

A. In September, 1913, the oil used was 2.799 pounds per ton based upon a ton of mill heads.

X-Q. 441. Mill heads to the flotation plant?

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A. Mill heads, that would be the heads to the mill, of new ore. That would make it slightly above that per pounds per ton of flotation feed.

X-Q. 442. When did you commence using pine oil?

A. We started to use pine oil about June, 1913.

X-Q. 443. And what was the oil proportions and the mixture at that time?

A. The amount of oil used July was 4.24 pounds, so it would be approximately four pounds.

X-Q. 444. The average oil used during July was 4.24 pounds per ton of what?

A. Per ton of ore to the mill.

X-Q. 445. MR. WILLIAMS: In what manner was that oil proportioned; was it oleic acid or pine oil or pine oil alone, or what proportion?

A. There were some days when pine oil was used alone, and some days when it was used with oleic acid, but I should say the proportion at that time, was about 50% of each.

X-Q. 446. I asked you for June.

A. There was only a day's run made with pine oil in June, consequently I gave you July.

X-Q. 447. How long did you continue to use a mixture of pine oil and oleic acid in the proportion of about 50% of each?

A. Well, the proportion varied from fifty to forty and sixty. We continued the use of pine oil and oleic acid for some time.

X-Q. 448. Until when?

A. Until the latter part of 1914.

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X-Q. 449. Then what oil did you use?

A. Then we used pine oil alone. We were, at this date here, using oleic acid together with pine oil in August.

X-Q. 450. When you used pine oil alone, in what proportion or amount did you use it?

A. Approximately after that it was 1.64 lbs. per ton.

X-Q. 451. What day's record have you given me?

A. That is December 30th, 1914, the average to date for that month. That gives you a fair average.

X-Q. 452. How long did you continue to use pine oil alone?

A. We continued to use pine oil alone, and being the principal oil that we used until December, 1916.

X-Q. 453. December first?

A. No, December 22nd, it being understood that the pine oil was the principal oil that we used. However, we had occasional carload of other oils that we tried out, such as Barrett oil and pine tar oils and oils of that sort, but the principal oil that we used was pine oil.

X-Q. 454. Well, take the record of November, 1913,<sup>b</sup> and give me the oils or the mixtures that you used during that month. The record that you now show me is for November, 1916, and that does not give you the information you want.

A. It does not, but the one previous to that, October 31st, 1916, will give you the average amount of oil for that month of October.

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X-Q. 455. Give me that figure.

A. 1.50 lbs. of pine oil.

X-Q. 456. Any other oils used during the month of October, 1916?

A. No other oils used.

X-Q. 457. Now, give me the record of October 31st, 1916.

A. The ore milled was 2,122 tons. The mill zinc concentrate obtained was 75 tons. The lead concentrate 20 tons.

X-Q. 458. That was water concentration?

A. By water concentration. The flotation concentrate that was obtained was 526 tons.

X-Q. 459. And the tailings?

A. The average assay of the tailings was 1.19.

X-Q. 460. The tonnage of the tailings?

A. Well, I will figure it for you.

X-Q. 461. That is not given on the sheet?

A. We do not keep the tonnage of the tailings, no. The tonnage of the tailings was 1,501 tons.

X-Q. 462. How did you compute it?

A. By subtracting the products that were obtained in the mill from the ore that was milled.

X-Q. 463. Now, give the assay of the concentrates from the flotation plant.

A. The assay of the concentrate of the flotation plant was, for the first shift, 55.2% of zinc; of the second shift, 55.3, and for the third shift, 55.6.

X-Q. 464. Now, what was the assay of the zinc concentrate from the water concentration part of the plant?

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A. For the first shift, 46.7; for the second, 48.4 and for the third, 47.9.

X-Q. 465. On that date did you use sulphuric acid?

A. On that day sulphuric acid was used.

X-Q. 466. In what amount?

A. I haven't it for the particular day, but I have it, the same as I have the oil, for the average for the month, to and including that day, which is 5.059.

X-Q. 467. Did you use heat on that day?

A. A very little heat was used; however, the temperature, as I remember it in 1916, we were operating at about 35° C.

X-Q. 468. And you used steam in order to get it up to that temperature?

A. Oh, yes.

X-Q. 469. Did you use any other reagents on that day besides those you have given?

A. On that day we used copper sulphate solution.

X-Q. 470. How much?

A. That was equal to one-tenth of a pound of metallic copper per ton.

X-Q. 471. Per ton of what?

A. Per ton of ore milled, the same as the oil and acid was based upon.

X-Q. 472. When did you commence to use copper sulphate?

A. It was about July, 1915.

X-Q. 473. And did you continue to use it from then on?

A. We did.

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X-Q. 474. When you started in July, 1915, how much copper sulphate did you use?

A. We used about .25 of a pound of metallic copper per ton of ore milled.

X-Q. 475. And when was that increased, or was it increased?

A. It was decreased.

X-Q. 476. And when was it decreased? And to what amount?

A. Gradually decreased until about the latter part of 1915, when it was found that the results were as good with one-tenth of a pound metallic copper per ton of ore.

X-Q. 477. And that is the figure—this figure that you give is not the figure representing the copper sulphate, but the figure which represents the amount of copper in the copper sulphate, is that right?

A. Exactly so, yes.

X-Q. 478. And that one-tenth of a pound of metallic copper per ton of copper sulphate, how long was that continued?

A. Well, that has continued up to the present time. Right now it is about .08, or a little less.

X-Q. 479. Any other reagents used besides what you have testified of?

A. None, other than as a settling agent, sodium chloride; we used salt.

X-Q. 480. Where?

A. For the slimes.

X-Q. 481. For the settlement of the slimes in thickening?

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A. In thickening.

X-Q. 482. And of course that salt goes into solution in the water?

A. It does.

X-Q. 483. And flows through the flotation plant?

A. It does.

X-Q. 484. Could you give me an idea of how much sodium chloride is present in the flotation plant as the result of that?

A. I could not.

X-Q. 485. What is the general measure of its use?

A. We measure it on the amount of ore that is milled, and that figure is about .87 of a pound for the month of October, 1916, per ton of ore milled.

X-Q. 486. .87 of a pound of sodium chloride?

A. Yes.

X-Q. 487. Do you continue to use sodium chloride or common salt for the settlement of slimes at the present time?

A. We do.

X-Q. 488. And in the same amount?

A. Substantially so, yes.

X-Q. 489. This copper sulphate solution that you used, from where did you obtain it?

A. The Anaconda Mining Company.

X-Q. 490. Have you any analysis of it?

A. Contains about 1.3 $\frac{1}{2}$ , approximately, of metallic copper; contains some salt and some acid.

X-Q. 491. Does it contain any copper chloride?

A. I have not made determinations for copper chloride on that.

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X-Q. 492. Do you happen to know what kind of a product it is?

A. It is the Leach solution which is obtained from the leaching plant of the Anaconda Company.

X-Q. 493. The solution that has done its work in the leaching?

A. No, the solution that results from the leaching by sulphuric acid.

X-Q. 494. And that is the copper sulphate that you have used in all your experiments here?

A. Exactly so.

X-Q. 495. Well, haven't you an analysis of that material that you can give me?

A. I might have with me, I am not positive about that. I can make a search and see.

X-Q. 496. Suppose you look it up and get it later so that the court won't have to wait?

A. All right.

X-Q. 497. How about the water that flows through your flotation plant? What is your water system? Where does the water come from that goes through the plant?

A. Why, part of the water comes from the North Butte extension property which is situated and located about a mile from the Butte Superior plant, and part of it comes from the city of Butte and the balance is reclaimed water that is used over again from the settlement of the slimes.

X-Q. 498. And from the concentrate?

A. Also from the concentrate.

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X-Q. 499. That is to say, you economize by getting the water out of your products and sending it back again through the system? Is that right?

A. Yes, sir.

X-Q. 500. Now, I want some of the proceedings after December 22nd, 1916. We will take the period from February 4 to 28th, 1917, and I note that you give the assay of the feed to the flotation plant as 13.29 per cent zinc, and the ore to the flotation plant plus circulating middling treated in flotation as 20.25 per cent zinc. How was that arrived at? By measurement or computation?

A. That was arrived at by determination, assay determination.

X-Q. 501. By assay of the total feed?

A. Ore to the flotation plant plus the circulating middling treated in flotation.

X-Q. 502. Now give me the figures about the circulating middlings. In the first place give me the tonnage of circulating middling?

A. I haven't the tonnage of circulating middling. The tonnage that is given here is the tonnage of ore to the flotation plant, 26,262 tons.

X-Q. 503. Is that new feed?

A. That is new feed which contains 13.29 per cent zinc. The ore to the flotation plant, plus the circulating middling treated in flotation contains 20.25 per cent zinc, but I have no tonnage of that material. It is impossible to get it.

X-Q. 504. Well, do you take a sample of this total

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feed and do you from this sample make an assay to determine the amount of copper in it?

A. As before stated, I make an assay to determine the amount of copper in it.

X-Q. 505. And zinc?

A. Yes.

X-Q. 506. And you do not consider the tonnage of the middlings returned?

A. No, the middlings returned go right with the original ore when it comes in; it is all elevated together to the machine.

X-Q. 507. Well, then, in the absence of that tonnage can you give me the zinc content of the middlings returned?

A. No, I can't give you the zinc content of the middlings returned.

X-Q. 508. Can you give me the amount of oil in the middlings returned?

A. I cannot give you the amount of oil in the middlings returned.

X-Q. 509. Or the percentage?

A. Nor the percentage either.

X-Q. 510. The only measurement that you have is the measurement of the amount of zinc in the middlings returned? Is that right?

A. The only measurements that I have is the amount of zinc in the feed to the flotation plant plus the circulating load; and I also have the oil determination for that material. That is the actual material that goes to the machine.

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X-Q. 511. Can you, Mr. Dosenbach, compute the tonnage of the middlings and the amount of oil in the middlings from these figures?

A. It might be approximately computed, if you have the two determinations and one tonnage.

X-Q. 512. State what your method would be?

A. Why, having the total tonnage to the flotation plant containing its relative amount of zinc, having the assay determination of the material to the flotation plant, which includes that tonnage of the original ore plus some indefinite tonnage that contains some indefinite amount of zinc, it might be possible to. I have not gone over it to see.

X-Q. 513. Have you a general idea of the richness of these middlings and the amount of zinc which they contain?

A. Why, it can be seen that if the feed to the flotation plant plus the circulating middlings that is treated in the flotation plant, which is the flotation machine feed, contains more zinc than the original ore did, why it is quite possible that the middlings returned is richer than the original ore that came in, so as to bring the average of the two up to a percentage, which in this case is approximately seven per cent richer in zinc than the original ore.

X-Q. 514. That is obvious. But I asked you whether you had any idea as to the richness of these middlings?

A. The middlings possibly might run on the average 25 or 30 per cent zinc.

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X-Q. 515. Of course if they run much higher than that they would not be returned as middlings? Isn't that true?

A. Yes, that is very true.

X-Q. 516. I think you made a general statement about the proportion of middlings returned to feed. Now, what definite basis have you for that statement? You said sometimes it was greater than the original feed?

A. Yes. The basis of that is that a glance at the tailings of the feed to the flotation machine itself would give you some idea that the amount of material returned is as great or greater than the amount of the original ore sent to the flotation plant.

X-Q. 517. Have you the original records of the days around February 4th to 28th, 1917?

A. I have.

X-Q. 518. Let me see them please?

A. I haven't them with me other than the tabulated data that gives each day's operation.

X-Q. 519. I would like you to bring with you the records upon which these tabulations were prepared for the period of February 4th to 28th, 1917. When you changed from the smaller quantities of oil to the somewhat larger quantities on December 22nd, 1916, what changes did you make in your mode of operations and the machines used and so forth?

A. There were no changes<sup>made</sup> in operations other than making provision for connecting the tube mill discharge direct to the flotation pyramid machine that

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was put in operation on that day, and also connecting a portion of the slimes which now were the general slimes that went to the general flotation plant to that machine itself.

X-Q. 520. Well, then, that machine was put in operation on that day? That was one change?

A. That was one change, naturally it would be.

X-Q. 521. You started with a pyramid machine and where did you feed the oil to this pyramid machine or the feed to this pyramid machine?

A. Just before it went to the first cell. That was considered in the series of rougher cells; that was #2 cell on that pyramid.

X-Q. 522. At what times during your operations did you feed the oil or any portion of it ahead of the tube mill?

A. We made frequent changes of that sort and fed the oil to the head of the tube mill at various times during the operation, but found that we did not obtain any better results with the oil going to the head of the tube mill than we did with the oil going to the feed after it left the tube mill or the tube mill proper.

X-Q. 523. How long at any time did you continue to feed the oil to the head of the tube mill or ahead of the tube mill?

A. Oh, possibly we continued for a period of four to six weeks.

X-Q. 524. And when was that?

A. That was after starting in December. We made experiments to see whether it would be advisable or

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not, and then we would disconnect it and send it to the other place.

X-Q. 525. After December 22nd, 1916?

A. Yes, that is what I am speaking of.

X-Q. 526. When did you last feed the oil ahead of the tube mill?

A. To the best of my recollection it was in March of this year, the latter part of March.

X-Q. 527. Were you in the plant on Sunday morning, before the arrival of our representatives, Sunday last?

A. I was not, no.

X-Q. 528. Prior to the use of the larger quantities of oil, that is to say prior to December 22nd, 1916, did you take any part of your concentrate as first concentrate from one of the machines without retreatment?

A. Please state that again.

X-Q. 529. (Question read.)

A. Yes, we have done that.

X-Q. 530. Over any considerable period of time?

A. Not for any great considerable period of time.

X-Q. 531. What was the general practice?

A. The general practice was to clean and reclean but occasionally when the system was overloaded and it was necessary to relieve a part of the system, why the concentrate from the rougher machine with the rougher concentrate was sent to the bin for a period for a sufficient time to enable the plant to readjust itself.

X-Q. 532. When did you commence to both clean and reclean your concentrates?

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A. In November, 1913.

X-Q. 533. When did you commence to clean and re-clean and again re-clean your concentrates as you were doing last Sunday?

A. We also did that in 1913, about the time, after November, 1913; our first cleaner was arranged so that we could make two cleaners out of it.

X-Q. 534. And then in addition to that there was a re-cleaner?

A. A re-cleaner; there was a third cleaner.

X-Q. 535. Can you give me any other comparative figures of the return of middlings to original feed before December 22nd, 1916, and after December 22nd, 1916?

A. I should say that they were approximately the same, or very nearly so.

X-Q. 536. When did you install the Callow machines?

A. They were installed in the latter part of 1915.

X-Q. 537. And for what purpose have they been used since their installation?

A. They have been used merely to take care of the fluctuations that occurred in the Janney machines that are placed in the system ahead of them—take the feed before they take the feed; for instance, if a Janney machine is down, or any part of it is down for any reason whatsoever, it sort of leaves the pneumatic machines below to take care of the feed as it goes to it.

X-Q. 538. What do you mean by taking care of the feed; do you use them for producing finished concentrates?

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A. We do not; we produce middlings from these machines only, and they are merely there as a safety valve, you might say.

X-Q. 539. Their function is to clean the tailings?

A. To assist in cleaning the tailings, yes, and as a safety valve to take care of any fluctuations in the upper part of the plant, should it suddenly go down, or any part of it go down.

X-Q. 540. Before December 22nd, 1916, did you take into account the oil in the circulating middlings?

A. We did not.

X-Q. 541. Since December 22nd, 1916, you have made frequent changes, have you not, in the flow sheets as to the flow of the material to the different machines?

A. Since December 22nd, 1916, yes. The plant was changed over from the straight series type of machines to the pyramid type of machines and that necessitated the changing of the flow sheets.

X-Q. 542. And then, as I understand it, the flow sheet as exhibited to us last Sunday was different from the flow sheet as you explained it to us on Saturday, is that right?

A. Well, I did not have time to conclude it Saturday; I was endeavoring to explain the cleaning arrangements, which I showed on that flow sheet to the two cleaning arrangements, and I endeavored to show this, consequently I did not draw any line for these machines except No. 7 pyramid, to give you the actual flow through the pyramids as original material.

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X-Q. 543. When did you commence to use one of the pyramid machines as a cleaning machine or re-cleaner?

A. In February, I think it was, when we started to use it; February, 1917. Then it was discontinued again, and then it was used again.

X-Q. 544. I notice that in Exhibit 158 in the period January 30th to February 3d, 1917, the estimated recovery is given as 99.20. I note also that in the daily proceedings sheet, Exhibit 159 for January, there is an item which you explained, on January 31st, 130.70% recovery estimated. Is that figure of the calculation the one which accounts for that very high 99.20 in the estimated recoveries from January 30th to February 3d?

A. I should say that it was.

X-Q. 545. So that that particular figure, 99.20, as a representative of the recoveries on the operations of this particular test, may be treated as having been greatly exaggerated by the ordinary methods of computation and balancing up at the end of the month, is that right?

A. At the end of the month, yes, sir.

X-Q. 546. You did not furnish any table of the daily operations from December 22nd to January 1st, did you?

A. No, because there was just a portion of the plant in operation with the larger quantities of oil at that time, and the pyramid machines, as shown in one of the reports, gives the results of that particular

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operation; that is, the tailings from the pyramids after the assays had been made which are reported on that sheet, joined with the other tailings and was taken as a general sample for our regular mill record.

X-Q. 547. That is to say, it was a period of experimentation, and the operations in the larger amount of oil were practically those that appear in the table, Exhibit 163, is that right?

A. I <sup>should</sup> say that it was a period of more or less oil used in the plant for the various machines, due to the fact that we did not have the oil to operate the entire plant, so we operated on what machines we had the oil for.

X-Q. 548. Why don't you say that it was because you were experimenting and did not know exactly how to handle the larger quantities of oil; that is the truth, isn't it?

A. It is not.

MR. SCOTT: Mr. Williams, I would ask you what you mean by large quantities of oil, whether you mean one thing or another.

MR. WILLIAMS: I think that the reports which the witness has produced of the test that I refer to are sufficient for the edification of the witness.

MR. SCOTT: Will you kindly state what you mean by large quantities of oil?

MR. WILLIAMS: Do you object to the question which I asked?

MR. SCOTT: I object to it because it is too indefinite—large quantities of oil. I refer to the last question.

Ben H. Dosenbach.

THE COURT: The witness apparently understood and answered. I think the objection comes too late.

Defendant excepted.

X-Q. 549. In the following report that you have given of the daily operations, I don't find the application of the oil of the 68 different varieties of oil mixture that are described. The 53 varieties of the regular operations, shown in Exhibit 160, do not appear in the daily reports, the last one being variety No. 50, on March 31st, 1917.

A. That is 50.

X-Q. 550. There is an interregnum, is there not, in the operations of April, wherein the other three of the 53 varieties were used, as to which you have furnished no information?

A. Well, as I said yesterday, we keep our oil in numbers, and it is the only way to keep general track of the oil mixture when we are using more than one oil; consequently these three oils must have been used on one of the days in April.

X-Q. 551. You have given a general summary of April 1st, 1915. Will you give a record of the daily operations?

A. I can supply a record of the daily operations, but I think it would take the afternoon. I have been so busy in April here that I have not had a chance to do that.

X-Q. 552. Please do that so as to complete the record, and make the daily records correspond at least for

Ben H. Dosenbach.

the latter part of the work, with your general flotation operation sheets.

A. All right.

X-Q. 553. Now, I don't find in here 53 varieties of regular operations, and these 16 varieties of experimental operations are operations in the pyramid machines—that is not the exact oil mixture that has been testified of here. When was that mixture adopted?

A. Well, as I told you, that is the mixture that we endeavor to run, and in a number of instances there, while the actual figures may not show it exactly, those are the actual proportions taken by weight and the figures 70, 18 and 12 is the oil mixture used. After 24 hours of operation, the oil mixture may come out 70, 16 and 14, showing the actual weights that had been used. That is necessary to keep track of our oils.

X-Q. 554. Variety No. 28 is 10% kerosene, 70% Jones' crude and 20% of pine, which seems to me to be the nearest approximation to what you have given.

A. That is fair all right, I should say.

X-Q. 555. Where do you get this kerosene?

A. Well, that is purchased from the Utah Oil Refining Company and from the Continental Oil Company and from the Texas Oil Company.

X-Q. 556. Is the kerosene such as is sold on the market for illuminating purposes?

A. As commercial kerosene, yes.

X-Q. 557. Isn't it a cruder and cheaper grade?

A. We have had one or two cars of a cruder, cheaper grade.

Ben H. Dosenbach.

X-Q. 558. What is the Jones crude oil, and where do you get it?

A. That is an oil that comes from Kansas; it is called Jones' crude, but I think it is more of a residuum than it is a crude oil.

X-Q. 559. Of petroleum?

A. Of petroleum, yes, sir.

X-Q. 560. The No. 1 creosote, what is that?

A. That is a hardwood creosote, a fractional distillate from the hardwood.

X-Q. 561. Where do you get that from?

A. That comes from Marquette, Michigan.

X-Q. 562. No. 2 creosote?

A. That is also another fraction of a hardwood distillate, it is a hardwood distillate, and is somewhat similar to the #1.

X-Q. 563. Do you know what the difference is between the two?

A. Well, it is a difference in the fractionating of the two.

X-Q. 564. Now what is this fuel oil?

A. The fuel oil is a paraffin <sup>residuum</sup>.

X-Q. 565. Is this known as Jones fuel?

A. It is not. That is known as Graybull fuel.

X-Q. 566. Where do you get it from?

A. From Graybull, Wyoming.

X-Q. 567. Now, the pine oil, where do you get that from?

A. Principally from the Yaryan Resin and Turpentine Company.

Ben H. Dosenbach.

X-Q. 568. Do you have any pine oil which is not Yaryan pine?

A. Right now we haven't, no.

X-Q. 569. But you have had?

A. We have had other pine oils that we have tried out. Everything in that report is Yaryan pine oil.

X-Q. 570. No. 4 Barrett, that is a wood tar, is it?

A. That is a coal tar distillate.

X-Q. 571. And where do you get that from?

A. From the Barrett Manufacturing Company.

X-Q. 572. What was this oil called tar?

A. That is crude coal tar.

X-Q. 573. And where do you get that from?

A. From the Butte Gas Works.

X-Q. 574. What is this paraffin base?

A. That is a crude paraffin oil or paraffin base.

X-Q. 575. Can you complete the supply of specimens of these oils that are tabulated by you? I believe we have one or two, but not by any means all.

A. I can.

X-Q. 576. Will you do so as promptly as possible?

A. I will if you will let me know what quantity you want?

X-Q. 577. Kindly talk to Mr. Chapman or Mr. Higgins and give them what they want. Will you do so?

A. Yes, if they don't want too much.

X-Q. 578. Now, during the period before December 22nd, 1916, did you make any determination as to the circulating middlings, any assays or measurements?

Ben H. Dosenbach.

A. No. We have at times endeavored to get some experimental data of these middlings, but the volume of material that we were returning was quite great and it was very hard to get an accurate tonnage sample, and an assay of that material so I have actually taken these samples and thrown them out, for I did not think they would be accurate enough to submit.

X-Q. 579. Then you haven't any reliable record of these middlings prior to December 22nd, 1916? Is that correct?

A. I have no reliable records on the middlings prior to or after December 22nd, as to the amount and the assay.

X-Q. 580. Do I understand that after December 22nd and during the period up to the present time you have had no reliable record of the middlings?

A. As to what?

X-Q. 581. As to any part of them?

A. No.

X-Q. 582. What did you mean when you said that you had no reliable record before or after December 22nd?

A. I meant that we didn't have any.

X-Q. 583. Well, now the figures that you have given in these daily returns, do you include those as unreliable?

A. Absolutely not. This is the middlings plus the ore and not the middlings alone.

X-Q. 584. Well, prior to December 22nd have you any figures that will show the middlings plus the ore feed?

Ben H. Dosenbach.

A. I have.

X-Q. 585. Give me a record of some time shortly before December 22nd, 1916?

A. I will have to supply them for you, Mr. Williams. I can supply all of December and November of 1916 for you if you so desire.

X-Q. 586. You commenced to make up that record in December, 1916?

A. No, we made it previous to that time, as to the assay of the flotation machine headings or the ore plus the circulating middling treated in flotation, and I can supply that for an average period or any time that you might wish.

X-Q. 587. Well, supply it for November and December, 1916, and then for December, 1915?

A. All right, sir.

X-Q. 588. Now, are we to have another flow sheet which will give the actual operations as they were exhibited to us on Sunday last?

A. I will supply you with another flow sheet of the actual operations as they existed on Sunday last.

X-Q. 589. Your Janney machines are operated with what speed of impellers?

A. About 570 revolutions per minute.

X-Q. 590. And can you give me the peripheral speed?

A. I can figure it for you.

X-Q. 591. Give me the diameters?

A. 20 inches for the upper impeller and 15 inches for the lower impeller.

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X-Q. 592. And is that maintained throughout the plant, that speed?

A. That is.

X-Q. 593. Have you used an oil known as Jones fuel oil?

A. We have used an oil known as the Jones crude oil.

X-Q. 594. Have you used an oil known as the Jones fuel oil?

A. No.

X-Q. 595. You haven't used any different varieties of Yaryan pine oil?

A. Yes.

X-Q. 596. Can you describe these different varieties?

A. I can.

X-Q. 597. Please do so?

A. One variety we have used was a pine oil that was comparatively pure, while other varieties that we have used were not so pure, containing more of the solvent material, such as the paraffin solvents that are used in the extraction of the pine oil from the wood. These pine oils having a lower specific gravity than the ones which were comparatively pure, which had a specific gravity of about 0.93.

X-Q. 598. Can you give a trade description of these different varieties?

A. The pure pine oil is the Yaryan standard pine.

X-Q. 599. And the other?

A. The others are #2 Yaryan pine.

Ben H. Dosenbach.

X-Q. 600. That gives two varieties. Are there any others?

A. There are others that range between the #2 and the standard Yaryan, which numbers I don't remember offhand.

X-Q. 601. But they have certain commercial numbers, have they?

A. I understand that they have. Some we have obtained samples of.

X-Q. 602. What are you using now?

A. We are using a mixture of the standard and the #2.

X-Q. 603. How long have you used them, about?

A. We have used them for the past several months, as we have not the tank capacity to keep them separated; we have to mix them.

X-Q. 604. Since December 22nd, 1916, what varieties of Yaryan pine oils have you used?

A. The standard and the #2.

X-Q. 605. And they have generally been mixed?

A. They have generally been mixed and in some instances have not, depending upon our tank capacity. We had room in one tank to put the lone oil.

X-Q. 606. Can you give me any figures giving the assay of the middlings or whatever you call it that is overflowed from the pneumatic or Callow plant?

A. A fair average would be between five and 12 per cent zinc.

X-Q. 607. And that is based upon your assays from time to time? Is that right?

Ben H. Dosenbach.

A. Yes. We don't assay them regularly, but we take occasionally a sample of it to determine its value.

X-Q. 608. Can you give me an idea of its tonnage?

A. That would be pretty hard. I have made no determinations on that particular matter.

MR. WILLIAMS: For the present and in view of the fact that there are so many other things that the witness has to supply I suspend the cross-examination.

#### RE-DIRECT EXAMINATION

BY MR. SCOTT:

R-Q. 609. You were asked on cross-examination something about when your attention was first called to using large amounts of oil, and you stated that—referred to some circumstance at the Utah Copper Company, I think, in the summer of 1913?

A. I did.

R-Q. 610. Will you explain that circumstance? What happened?

A. It was in the summer of 1913 when I went to Garfield, Utah, to the Utah Copper Company to assist in some flotation work for a period of two or three months. While there we determined the best methods that we knew of to float the ore or rather the low grade concentrate, and it was found that by only using coal tar or its derivatives, or a mixture of coal tar with the crude oils that good results were obtained when using a large quantity of the oil; and it was impossible to get the results at that time with a smaller

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quantity. By "large quantity" I mean we had used as high as thirty and forty pounds of oil per ton, at that basis, in the small apparatus, and the results were very much poorer with quantities that were smaller than that, say ten pounds or five pounds; and with a smaller <sup>quantity</sup> one or two pounds, we couldn't get anything. And at that time it was upon this investigation that we determined the relative importance of large quantities of oil.

R-Q. 611. Can you state about how much insoluble the Butte & Superior ore carries, mill run?

A. On an average I should say between 65 and 70 per cent. A fair average would be 67 per cent insoluble.

R-Q. 612. What would be the figure for the flotation feed?

A. Well, the flotation feed would be somewhat higher than that, possibly 72 per cent.

R-Q. 613. On account of what?

A. Having some mineral taken out of the original ore.

R-Q. 614. When you began to use upwards of one per cent of oil was the time of agitation, or the degree of agitation, time of agitation, changed in the Butte & Superior plant?

A. It was not.

R-Q. 615. Did you ever use copper in a different form from that you referred to as being purchased from the Anaconda Company?

A. Yes.

Ben H. Dosenbach.

R-Q. 616. In what form?

A. We have used copper sulphate, a solution produced from the copper sulphate crystals.

R-Q. 617. Ordinary commercial crystals?

A. Yes, ordinary commercial crystals.

#### RE CROSS-EXAMINATION.

BY MR. WILLIAMS:

RX-Q. 618. When did you use copper sulphate produced from crystals?

A. We used that when we first started the operation in 1915 with copper sulphate. The first copper sulphate that we used was made from crystals, made into a solution.

RX-Q. 619. And about how long did you use that kind of copper sulphate?

A. Well, I don't remember exactly when we started using the A. C. M. solution, the Anaconda Copper Mining Company solution; but I do know this: at various times it has been difficult to get the Anaconda Mining Company's leach solution, and it is necessary for us to use the copper sulphate solution. We keep a stock of it on hand at all times and can change to the copper sulphate crystal solution, which gives equally as good results as the Anaconda Mining Company's leach solution.

RX-Q. 620. Well, you can give me a general idea as to when you commenced using the Anaconda Mining Company leach solution, can you not? Please do so.

Ben H. Dosenbach.

A. About a year ago, I think, approximately.

RX-Q. 621. MR. SCOTT: Have you drawings of these machines you have used in your experiments, or some of them?

A. Yes, I have.

RX-Q. 622. Have you them with you?

A. I have. I have a drawing here of the cataract machine that I used in producing the Everson procedure.

MR. SCOTT: We will put this in evidence if there is no objection, so they will be convenient in the record to refer to the different types of machines.

MR. WILLIAMS: No objection even to the violation of the fundamental principles of perspective that appears in the drawings.

MR. SCOTT: I offer the drawing of the cataract machine in evidence, this being the machine used by Mr. Dosenbach in one of his Everson experiments.

THE COURT: What machine was that?

MR. WILLIAMS: Out of the German publication. It is the oil purifying machine. Of course I have a general objection to the use of that machine.

THE COURT: It will be admitted.

Drawing admitted in evidence and marked DEFENDANT'S EXHIBIT 182.

RX-Q. 623. MR. SCOTT: Have you drawings of any of the other apparatus?

A. Here is the Janney machine.

MR. SCOTT: We offer in evidence a drawing

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showing the Janney circulating machine in section, this being a drawing of the machine used by Mr. Dosenbach in one of his experiments.

MR. WILLIAMS: I suggest that that be corrected to properly represent the machine that is in evidence. The correction is not a large one and can easily be made, showing the dome top. With that correction I have no objection.

THE COURT: Well, the correction will be made.

Drawing admitted in evidence and marked DEFENDANT'S EXHIBIT 183.

MR. SCOTT: I offer in evidence, drawing of the square glass jar machine used by Mr. Dosenbach in his experiments.

Drawing admitted marked DEFENDANT'S EXHIBIT No. 184.

RX-Q. 624. MR. WILLIAMS: In regard to defendant's exhibit No. 182, representing the so-called cataract machine, I observed at your plant an oil mixing machine provided with a revolving impeller and baffles, or at least one baffle. You have that construction in mind, have you not? The oil mixing machine at your plant which was mixing the oil that you ~~were~~ was using on Sunday last?

A. Yes.

RX-Q. 625. That machine has a revolving impeller about the same as in this cataract machine, has it not?

A. It has a revolving impeller.

Ben H. Dosenbach.

RX-Q. 626. About the same as this cataract machine?

A. No; it has a very narrow blade.

RX-Q. 627. It has a baffle, has it not?

A. Yes, it has a baffle.

RX-Q. 628. At what speed is it rotating in your plant, mixing the oil?

A. It is rotated at about twelve to fourteen—I should say offhand—revolutions per minute. I wish to say, however, that the oil is placed in that oil mixing tank up there, and it is not necessary to revolve the impeller any faster than it is going for the purpose that we desire.

MR. SCOTT: I offer in evidence the Janney circulating machine which Mr. Dosenbach used in his experiment.

MR. WILLIAMS: The machine, while of interest, is irrelevant as to any of the issues in this case, because the record shows that it is a machine that was invented about 1913 or 1914, and is therefore, and can not therefore, be any part of the prior art. I should like a ruling upon that, if your honor please.

THE COURT: Well, the court will allow it to be admitted. The objection is overruled.

Plaintiff excepted.

THE COURT: Experiment has been made with it before the court, and to repeat them, perhaps the machine ought to be here. The exception will be noted.

Ben H. Dosenbach.

MR. SCOTT: I offer in evidence the machine used by Mr. Dosenbach in his experiments and referred to as the cataract machine, the same following the German publication referred to by Dr. Sadtler.

MR. WILLIAMS: The same general objection; it is no part of the prior art.

THE COURT: For the same reasons the court will overrule the objection, and exception will be noted.

Machine admitted in evidence and marked DEFENDANT'S EXHIBIT No. 186.

MR. SCOTT: I offer in evidence the machine used by Mr. Dosenbach and referred to as the Fryer Hill machine.

MR. WILLIAMS: The objection to the introduction of that machine of course repeats the objection that was made to the experiments in it. That machine is a figment of the imagination of counsel, and has no part in the record or in the proceedings in court, and I object to it on the ground that it is incompetent, irrelevant and immaterial.

MR. KREMER: I don't know whether that is a compliment or not, Mr. Williams.

MR. WILLIAMS: It is a compliment to the ingenuity of counsel.

THE COURT: It is the opinion of the expert that the machine follows the publication, and experiments have been made with it, and for the same reason the court will allow the machine to be introduced in evi-

Ben H. Dosenbach.

dence and the objection will be overruled and exception allowed.

Fryer Hill machine admitted in evidence marked DEFENDANT'S EXHIBIT No. 187.

MR. SCOTT: I offer the square glass jar machine in evidence.

MR. WILLIAMS: The general objection as to that. The particular objection was to the speed at which it was rotated.

Objection overruled; plaintiff excepted.

Machine admitted in evidence and marked DEFENDANT'S EXHIBIT No. 188.

MR. SCOTT: I offer in evidence the cone Gabbett apparatus, including the up-cast appliance.

MR. WILLIAMS: As these are reproductions of the real prior art, as far as I can see, there is no objection.

Machine admitted in evidence, marked DEFENDANT'S EXHIBIT No. 189.

Whereupon further hearing was adjourned until 2 o'clock p. m. May 1st, 1917.

Prof. Wilder D. Bancroft.

2 o'clock p. m., May 1st, 1917.

PROF. WILDER D. BANCROFT recalled for further

DIRECT EXAMINATION

BY MR. SCOTT:

Q. 1. You have called my attention, Prof. Bancroft, to the fact that in your testimony the other day, appearing on page 1106 of the typewritten transcript, some of the percentages you mentioned were not stated accurately.

A. Yes. I stated that one-tenth of one per cent of oil on ore was approximately 6% on mineral when the ore contained 17% mineral, and was 25% of oil to mineral when the ore contained 4% mineral. That seems to have been a case of getting lost on the decimal point; those figures should be 0.6 and 2.5 respectively, which rather spoils the burst of eloquence that I indulged in. Of course if I had realized that the decimal point was misplaced I should have said things running from 0.1 to 1%, instead of doing it as I did.

THE COURT: It seems you were indulging in agitation right then.

A. It certainly looks like it.

Q. 2. BY MR. SCOTT: Professor, will you please tell us when you first saw a mineral froth, one of these concentration mineral froths?

Prof. Wilder D. Bancroft.

A. Well, as near as I can fix it, it was either the end of March or the first few days of April of this year.

Q. 3. How did you happen to see it then?

A. Why, because Dr. Sadtler telegraphed to me in the middle of the month of March to know whether I would consider coming out here and testifying in this case, and I told him that I could not tell until I had talked the matter over with him, because, as a matter of fact, I did not know which side Dr. Sadtler was on, and after that, of course, I began to get fairly busy looking up the details, because before that I had been simply interested in the general theory of it as a minor problem in colloid chemistry.

Q. 4. Your previous interest in it had been entirely disconnected from the concentration of ores; was that the case?

A. Oh, yes; I did not care anything about that. The thing that interested me in it has been that it is a practical application which connects in with two apparently different things; that is, we have emulsions, which are drops of one liquid—cod liver oil, for instance, suspended in another, and those drops are stabilized by adsorbed solids, and I have been doing a great deal of experimental work, or having it done, in the last few years, on the theory of emulsions. The next step is the theory of froths, because you can consider a froth as an extreme case of an emulsion, where you have got air or any gas, which may be considered as a very dilute liquid, instead of the liquid. One al-

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ways likes to make occasional reference to the fact that these things that we have been talking about are of interest from another point of view than the purely theoretical, because the student is much more interested in the practical side than in the other, and of course the bulk oil process does come in under this head, where you have two layers of liquid separated by the metal. But the only experiments that I have ever done was this same one that has been done here, of the copper powder and of the aluminum powder.

Q. 5. Then I take it that the lectures—I think you said one lecture a year that you had to deliver—for the past three or four years, have been devoted to this theoretical and scientific aspect of the emulsions and of froths?

A. Yes, to show the connection between emulsions and froths, and that we did have these particular things coming up as a special technical application, but of course as far as I was concerned, I never cared or really knew anything about the special details, because it was perfectly obvious that if we had air in there the things would float better than if we did not have air, and from the scientific point of view the problem never came up as to the special requirements or the methods of doing it.

Q. 6. Certain passages have been quoted to you from your article in Metallurgical and Chemical Journal of June 1st, 1916, the quoted passage relating to the nature of mineral floats formed with different quantities of oil. Were these statements based upon

Prof. Wilder D. Bancroft.

your own investigation or upon information otherwise obtained?

A. Why, they were based on information otherwise obtained; that is, we had done no experiments, as is shown in the statement seven lines from the end of that article: "We have not yet made any experiments on the factors affecting ore floatations when the oil is reduced to a minimum, so I will not discuss that point at all."

Q. 7. Now, referring to the passage from this article, Metallurgical and Chemical Engineering, which was quoted in question 221, appearing at page 1144 of the typewritten transcript, have you found anything from investigations made by yourself to confirm the statements contained in the quoted passage?

A. From experiments that we have done this winter on the theory of froths, and from the experiments that I have also done since I have been out here, I satisfied myself, somewhat to my sorrow, that that is all wrong, and that it was a very unfortunate paragraph to have written.

Q. 8. Will you state how you originated the series of experiments that you made when testifying the other day?

A. It was perfectly clear to me that you ought to be able to stabilize a froth with any solid which would be adsorbed ~~by~~ <sup>to</sup> it; and, if I were considering it purely from a scientific standpoint, I would have been satisfied to let it go with the statement of the fact that you could stabilize it with zinc sulphide or lead sulphide.

Prof. Wilder D. Bancroft.

But my experience has been that in every particular industry the people think that there is something specially mysterious about that and that the ordinary laws do not apply to it. That is, the literature is full of the statements that ore flotation is essentially mysterious and uncanny. If you take the people who make leather they will tell you that tanning is entirely different from any other industry under the sun, and that no laws apply to them. You hear people say the same thing if you talk to the people who dye cloth, that is they consider that the dyeing of cloth is quite different from anything that anybody else has ever known anything about, all of which is of course not so. So it seemed wiser to take other substances which were not directly connected in any way with flotation, and Messrs. Taggart and Beach talked the matter over with me to decide what substances would be the best for the purpose of these tests. We decided on lycopodium powder because we knew that that was not wetted readily by water, and consequently had a distinct adsorption for air. We took white lead because I knew that linseed oil will displace water from white lead. While I did not know that the same thing would hold in these other cases, it seems<sup>ed</sup> to me very probable; and the time being short we did not want to run a number of things that were likely not to work. We took lamp black because I knew that the different forms of carbon black have very strong adsorbing power and that among other things acetic acid is adsorbed by lamp black; so that these seemed to be the best things to start in with.

Prof. Wilder D. Bancroft.

I have no doubt we could find dozens of other things if we had time but it would take us about two days to show them.

Q. 9. Are there any other passages in the "Engineering and Metallurgical Journal" that you would like to comment on?

A. I have marked several passages in here which do not represent at all my present views. As regards to the other paragraphs they are not all worded quite the way I should do it now, but they are substantially correct. First, there are two typographical errors which I should like to correct. On page 632, in the paragraph beginning with the word "Winkleblech" the word "benzene" in there should be spelled with an "i," <sup>u</sup>bezine and not with an "e." In the next paragraph the word "benzene" should also be spelled with an "i" in the first place in which it occurs. It is all right in the second. Those are small typographical errors which were not corrected because I did not see the proof. Now, as to the paragraphs which are pretty bad from the present point of view. On page 634 all the way from the paragraph on the left column beginning "A large bubble" to the end of the paragraph on the right hand <sup>u</sup>colmn ending with "more air would give a plastic mass; with still more would give the bulk oil process." The statement in that about saponin is all wrong, and the part in there about the cause of the variation in the amount of oil is also wrong. While there are occasional sentences in there that are all right, it is safer to object to this

Prof. Wilder D. Bancroft.

whole thing. On page 635 the paragraph beginning "If a pure liquid does not form a froth with air" should come out. It is a perfectly suitable paragraph in itself but as I now know it doesn't have anything to do with flotation. That point as a matter of fact is covered in my testimony the other day. On page 635 the sentence reading "Now that we are a little more clear as to the cause of frothing" should also come out because I wasn't so clear in regard to the question of frothing, especially not as regards the theory of frothing agents, as I am now. With these exceptions I think the other is practically all right. Anyhow, I am willing to be responsible for it as representing substantially my views at the present time.

MR. SCOTT: I will try and get you another one of these if you will give me this one to put in evidence

A. Yes, sir.

MR. SCOTT: I offer a photographic copy of the article in the "Metallurgical and Chemical Engineering" by way of explanation of the testimony. Any objection?

MR. WILLIAMS: No, no objection.

Document admitted in evidence and marked  
DEFENDANT'S EXHIBIT 190.

MR. SCOTT: You may cross examine.

MR. WILLIAMS: No cross examination.

WITNESS EXCUSED.

Frank R. Wicks.

FRANK R. WICKS, recalled, testified as follows:

DIRECT EXAMINATION,

BY MR. SCOTT:

MR. SCOTT: Mr. Wicks will testify to one of these reports regarding which Mr. Dosenbach's employment was insufficient to cover the period.

Q. 1. I hand you the tabulated report of the Butte & Superior Copper Company, flotation operations covering the period from 1913, first quarter, down to April, 1915, and ask you if you were connected with the operations there referred to for any period of the time?

A. I was connected with the Butte & Superior operations from December, 1912, until April, 1915, which would include this period.

Q. 2. In what capacity were you connected with the company.

A. I had the title of mill superintendent.

Q. 3. And you did actually have the superintendency of the mill?

A. Yes, sir, I was in direct charge of the mill.

Q. 4. And these operations were under your charge?

A. Yes, sir.

Q. 5. And you can and do state that these figures correctly represent the operations?

A. I have studied them over and I believe that they are; yes, sir.

Q. 6. Now, Mr. Wicks, have you compiled any figures showing the details of operations in the Chino

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plant covering periods when the kind of oil used remained substantially the same?

A. Yes, sir, I prepared a tabulation for the month of November, 1916.

THE COURT: This is not a matter that he has heretofore gone over?

MR. SCOTT: This is another branch of the case we are going to take up. We are going to establish the relations between the amount of oil and other elements in the process for the purpose of showing that that is not related in any way to the weight of the ore itself.

THE COURT: I asked is it a matter that he has gone over before.

MR. SCOTT: No, he has not touched on this; no witness has, your honor.

THE WITNESS: These really furnish some information that Mr. Williams requested of me.

MR. SCOTT: What question of Mr. Williams brought this point up?

A. Mr. Williams was looking over the statements showing the details of operation of the vanner concentrate flotation plant at the Chino Copper Company, and he called my attention to the variation in oil and that it was in direct ratio or in direct proportion to the fluctuations in the dilution of the feed. I told Mr. Williams that that matter had never been called to my attention particularly but that it would appear from the statements that there was some relationship. So I got up some figures to show the details of that so as

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to show whether there was any comparison or not, and when I was doing that I also prepared a statement —some statements showing the relationship between the total sulphides in the ore and the amount of oil used, which was a matter that I also mentioned to Mr. Williams at the time I was testifying about that statement.

Q. 7. Now, the figures upon this statement which you have prepared are derived principally, are they not, from the tabulated statements that you produced the other day?

A. Yes, sir, the figures are taken from that or they are computations made from those figures.

Q. 8. Has an investigation or study of these figures been made for the purpose of determining whether there is some relation between the amount of oil and the sulphide in the ore and the solution?

A. Yes, sir. I was much interested in that and I proceeded immediately to tabulate it to see what the relationship was.

Q. 9. And has this investigation put in more definite form than this statement?

A. Well, in collaboration with Professor Taggart we prepared some charts showing graphically the relationship which the figures indicate on this sheet which I have here.

MR. SCOTT: You may cross examine because Professor Taggart will explain the calculation. I offer the statement produced by the witness entitled "Chino Copper Company, Hurley plant, data compiled from statement, form 12C, showing results of operation of

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vanner concentrate flotation plant, month of November, 1916."

MR. GARRISON: We, of course, object to this as not having any probative force, if your honor pleases.

Q. 10. Is it not true, Mr. Wicks, that in the operation of the flotation plant the following factors are liable to variation: first, tonnage fed to the plant per unit of time, 24 hours being the period usually employed?

A. Yes, the tonnage varies considerably.

Q. 11. How about the kind and amount of oil?

A. The kind and amount of oil varies somewhat.

Q. 12. How about the degree of agitation and aeration?

A. The duration and degree of the agitation do not vary a great deal. There is a little variation from time to time, but not a great deal.

Q. 13. Kind and quantity of reagents other than oil, is there a variation in that?

A. Yes, sir.

Q. 14. Is there a variation in the temperature of the pulp?

A. Yes, the temperature of the pulp varies according to the weather conditions.

Q. 15. Is there a variation in the quantity of the feed?

A. A considerable variation.

Q. 16. Is there a variation in the quantity of sulphide in the feed?

A. Yes, a great deal.

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Q. 17. Is there a variation in the quantity of oil used?

A. Yes.

Q. 18. Now, in your plant, when using the minimum efficient quantity of oil, if all the conditions above mentioned remain constant except the percentage of water in the feed and the quantity of oil used, what change do you make when the percentage of water in the feed increases?

A. Well, I find from this tabulation that I have prepared that as the percentage of water increases, the amount of oil used increases.

Q. 19. In your plant when using the minimum efficient quantity of oil, if all conditions remain constant except percentage of sulphide in the feed and quantity of oil used, what change do you make when the percentage of sulphide in the feed increases?

A. When the percentage of sulphide increases more oil is required and more oil is added.

MR. SCOTT: Now, the purpose of the tabulation that we offer, if your honor please, is to show by computation and graphic diagrams actually made from the records of the mill, that the observation of the fact stated by the witness is verified, and thereby to show that whereas the patent here in suit states the quantity of oil in terms of a percentage of the weight of ore, as a matter of fact there is no relationship of that kind whatever; that the quantity of oil is related to other things entirely, namely, to the sulphide content of the ore, to the dilution of the ore pulp and

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to other factors—as stated by one of the witnesses some time ago, to the degree of aeration as affecting the number of bubbles and the air surfaces in the pulp. It is our point that the patent in suit not only erroneously states by implication or by direct statement—I might say that there is what has since been called a critical point that the oil must be reduced to in order to produce this froth—we not only deny that allegation, but we also deny that the very terms in which it is stated have no relation to this process whatever, namely, a relation to the quantity of ore.

I renew the offer of this report.

MR. WILLIAMS: I have no objection to this report as it appears to be an illustrative diagram prepared to illustrate a theory; but now that we have the detail of these daily operations in this argumentative form, I think that should be supplemented by the details of these operations in the form in which they are summarized, and not particularized, in the record of the flotation operations of the retreatment of vanner concentrates, exhibit No. 29. If, therefore, this witness will supplement this argumentative report with a regular daily report of the operations, which will really give the basis for the argument, there is no objection to having this in evidence as an argument.

MR. KREMER: That is really a matter for cross examination, it seems to me.

THE COURT: What is this but a daily report?

MR. KREMER: So it is; the details of that daily report are subject to cross examination.

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THE COURT: It is nothing more nor less than a gathering together of the figures which appear elsewhere scattered through the various reports presented by the witness.

MR. SCOTT: Exactly.

THE COURT: Of course it adds nothing to the force of his testimony, but it is simply a handy and convenient way of gathering them together, I take it.

MR. WILLIAMS: It is a selection and computation, especially arranged from that record, not to the fundamentals of mill operation, but simply the presentation of an argument; and if this is supplemented by a report giving the information in the same detail that it appears in exhibit 29, there is no objection to having it in evidence.

THE COURT: Isn't that already in evidence?

MR. KREMER: It is already in.

MR. WILLIAMS: No, not the details of it.

Q. 20. THE COURT: As I understand it, this document shows—proposed exhibit No. 191 shows that on the 1st of November, 1916, you used 8.06 lbs. of oil, and on that day the pulp contained solids 46.03?

A. Yes, sir.

Q. 21. And so on?

A. Yes, sir. The first four columns, the figures are copied directly from the original record, and the remainder of the columns with the exception of the sixth one, are computations based on these figures. May I explain that further?

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Q. 22. Yes, you may explain.

A. The first four columns are copied directly from the original record, the pounds of oil per ton, the per cent. of solids, the ore treated per 24 hours, the assay for copper and all are copied from this original statement covering the operations of the vanner concentrate plant for the month of November.

MR. KREMER: It is now in evidence?

MR. SCOTT: No, it is not in evidence.

MR. KREMER: Then I made a statement that, that was wrong.

A. (Continued) The next column which is headed "Percent Cu<sub>2</sub>S is derived from the preceding column.

Q. 23. BY THE COURT: What is Cu<sub>2</sub>S?

A. That is copper sulphide in the form of chalco\$ite, and that figure, 4.51, is derived from 3.60 in the preceding column, that is, converting the metallic copper into sulphide, in the form of chalco\$ite, which is the form in which our copper exists.

Q. 24. BY MR. SCOTT: You mean that the first figure in that column is the copper as metal?

A. Yes, sir.

Q. 25. And in the next column you coimbine that copper with the sulphur that occurs with it?

A. Yes.

Q. 26. And that column gives the weight of the mineral in which the copper occurs?

A. Yes. Now, the next column which is headed, "Assay Percent Iron 17.8" that is also copied directly from this statement. Now, the next column is the

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percent iron which exists as FeS<sub>2</sub>, which is iron pyrite, or a sulphide form of iron. Then the next column is the percent of computed sulphide in metallic iron. You see the 14.4 is computed from the 6.7. One column is the metallic iron and the next column is the iron pyrite, and then the last column, 18.9 that is the sum of 14.4, which is the iron sulphide, and 4.51, which is the copper sulphide.

Q. 27. BY THE COURT: You can furnish or have accessible to the opposing party, the daily records from which this is made up, can you?

A. Yes, sir.

MR. GARRISON: If your honor please, may I call attention to a matter that is seriously embarrassing to us. We are only furnished with one copy of these papers, which Mr. Williams has to have, and all these explanations are lost to us because the experts have no copy, and it seems to me that we ought to have two copies of these papers so that our practical men might have them.

THE COURT: Well, I see—You can have this one that I have, because I don't know that it aids the court very much; the court follows the testimony. Both sides ought to be as agreeable as possible and accommodate both parties so they can follow the testimony.

MR. SCOTT: It is unfortunate we have no more copies.

MR. KREMER: We have no more on our side.

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MR. GARRISON: You had an extra one to give to Professor Beach that might have come to us.

MR. KREMER: Professor Taggart has one from which he is going to testify presently. I myself have none.

MR. GARRISON: I think the court could make a ruling that they furnish two copies of these papers to each side.

THE COURT: It should be done. The court can only say what should be done in future. You had better deprive your own expert of one and let the others have it. Your own expert will have plenty of opportunity to look at it in time.

MR. KREMER: If your honor please, I made the statement that this was in the record in tabulated form. That is not correct. Mr. Williams interrogated the witness on cross examination about this particular month, and in that way the major portion of the first four columns came into the record.

THE COURT: The objection will be overruled.  
Plaintiff excepted.

Tabulation referred to admitted in evidence  
marked DEFENDANT'S EXHIBIT No. 191.

Frank R. Wicks.

### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 28. I note that in the first items of exhibit 191, the assay of the iron is 17.8. The percentage of iron as FeS<sub>2</sub>, or sulphide of iron, is 6.7. In what condition does the remainder of that iron, the difference between 17.8 and 6.7, exist in the material described?

A. Principally as magnetite, which is an oxide of iron.

X-Q. 29. And does magnetite enter into the froth to any substantial extent?

A. Very little.

X-Q. 30. You would not consider magnetite, which is the magnetic oxide of iron, as a substance of a metalliferous character, that is, having a metallic luster and responding to the condition that float sulphides?

A. It is not a sulphide and does not respond to the treatment which ordinarily floats sulphide.

X-Q. 31. You don't float much of your magnetite?

A. No, sir; we try not to, and it floats to a very, very limited extent.

X-Q. 32. Then, as I understand you, the last column shows what may be termed the metalliferous mineral contained in the material?

A. It is intended to be the total sulphide content of the material treated.

X-Q. 33. What is there in that material besides the 18.9% sulphides; you have stated the magnetite.

A. Yes. There is a little oxidized iron, but very little, and then the remainder is gangue.

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X-Q. 34. Any hydrated iron oxide?

A. I don't know the condition of the iron that exists in there in solution.

X-Q. 35. As I remember it, when I cross-examined you, you showed me a table of the daily operations for the month of November, did you not?

A. Yes, sir.

X-Q. 36. May I look at that table for November, 1916?

A. Yes, sir; this is the one that you wanted a copy of.

X-Q. 37. Will you supply a copy of that table to me?

A. Yes, sir, I will be glad to.

MR. WILLIAMS: That is the document that I wanted to have, your honor, for the purpose of comparison.

X-Q. 38. Will you supplement that by a description of the materials used under the head "Pounds Used of Reagents." That, as I understand it, is the other reagents other than those described in other parts of the column—or have you that information at hand?

A. I have not that information at hand, Mr. Williams.

X-Q. 39. How long will it take you to get it?

A. Probably five or six days.

X-Q. 40. Will you obtain it and let me have it.

A. Yes, sir, I will endeavor to get it for you.

X-Q. 41. Now, you have made a statement that the oil increases with the increase of the sulphides. Upon what experience do you base that conclusion?

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A. Well, that is something that has been clear in my mind for a considerable length of time, because of my familiarity with flotation operations, and it might be particularly illustrated by the large difference in the oil consumption between ~~our~~ plants which are treating high grade material, such as this vanner concentrate plant which is under discussion—and the other plant which treats the low grade or vanner tailings. For instance, if we are using the Barrett No. 4 creosote oil in both plants, the oil consumption is very considerably greater in the plant which treats the vanner concentrates than it is in the plant which treats the vanner tailings.

X-Q. 42. Is that the sole foundation for your belief, aside from what these tables show that you have just produced?

A. Well, it has been a matter of observation for a long time; I have believed it to be true for the greater part of my experience in flotation.

X-Q. 43. You gave a great variety of variation of conditions which affected the operation of the plant. They all contribute more or less, I suppose, don't they?

A. Yes, they do all contribute to the results or lack of results that one is able to obtain from the plant.

X-Q. 44. As a matter of fact the man who runs the plant does not need to bother his head with these various considerations that you are talking about?

A. You mean the operator of the machine?

X-Q. 45. The operator.

A. Yes, he is expected to get results, and he has to take care of those things.

Frank R. Wicks.

X-Q. 46. How do you instruct him to regulate the plant?

A. We instruct him to get results?

X-Q. 47. How is he to get them?

A. By experience and by training, which is obtained from the men ahead of him, and of course by consultation with his foreman, and with the metallurgical department and with myself.

X-Q. 48. What is the principal thing that guides him in his judgment?

A. The assay of the tailings and the assay of the concentrates.

X-Q. 49. He does not get the assay of the tailings and the concentrate at the time that he has to make the adjustment, does he?

A. He gets the assay of the tailings every two hours; they take samples every two hours of the tailings and make assays, as a guide. The assay of the concentrate is made only from shift to shift; so that he gradually learns by experience and the appearance of the froth which runs a certain grade of copper.

X-Q. 50. Isn't it a fact that the appearance of the froth is the principal thing that guides him in his manipulation of the plant?

A. No, I think not.

X-Q. 51. Don't you think that he gets the appearance of the froth, and then he learns from the assays what that appearance means, and then he is guided largely by the appearance of the froth?

A. Well, I think he is guided more by the assay of the tailings than any other thing.

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X-Q. 52. And you get that information two hours after the trouble has happened?

A. No; a sample is taken every two hours, and it probably takes thirty minutes <sup>f</sup>or such a matter, to get the assay after the sample is taken.

X-Q. 53. What experience have you had in running the plant?

A. In running the plant itself? Considerable.

X-Q. 54. And have you made these various adjustments?

A. Yes, sir, personally.

X-Q. 55. And have you always waited for assays before you made the adjustments?

A. Not always.

X-Q. 56. You have usually been guided by your judgment of the appearance of the froth, haven't you?

A. I am guided chiefly by the looks of the froth in the machine. The conditions are repeated to get the bulk of the mineral in certain cells of the machine. If the conditions are not right you get a large proportion of the mineral toward the lower end of the machine and consequently more of it is carried into the tailings.

X-Q. 57. And that I should say was the relative froth appearance in the different boxes?

A. Well, I think it might be more properly stated as the volume of the froth rather than the appearance of it.

X-Q. 58. Examining this table, exhibit 191, I find that on November 28th you used 18.41 pounds of oil and your total sulphides were 34.6. On November 27th you used 17.85 pounds of oil and your total sulphides

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were 44.9. Does this seem to your mind to show that the amount of oil increases with the increase of sulphides?

A. I am rather inclined to think, Mr. Williams, that that assay of iron on the 27th is wrong, but the records showed that and so that is what I put in. However, it appears to be a very erratic point. In explanation of that I might say that the concentrate for that day contained 33.5 per cent of iron which was very considerably greater than any other single day during the month.

X-Q. 59. The last figure that you have given me was taken from the detailed statement which you are going to put in evidence later? Is that right?

A. Yes, sir.

X-Q. 60. Did you have mill experience at the Butte & Superior Copper Company?

A. Yes, sir.

X-Q. 61. Your ore there was a great deal richer, wasn't it?

A. Yes, sir.

X-Q. 62. When you were there how was the ore running?

A. Well, it was varying considerable. I think it went up as high as 22 per cent zinc at times, but it was very unusual.

X-Q. 63. I note that in exhibit 158, in the first quarter of 1913, the pounds per ton of oil were 4.76 and the pounds per ton of acid were 1.68 and that the apparent recoveries were 65.34 per cent. That is a very poor operation, wasn't it?

Frank R. Wicks.

A. I haven't that statement, Mr. Williams.

X-Q. 64. You just verified it?

A. I know I have but I can't recall those figures.

(Question read.)

A. Yes, sir, that is very poor.

X-Q. 65. And that is an operation with too much oil and too little acid, wasn't it?

A. I am inclined to think that it was not due to too much oil because the next quarter the amount of oil nearly doubled and the recovery went up twenty per cent.

X-Q. 66. And the amount of acid was more than double, wasn't it?

A. Yes, sir.

X-Q. 67. And then in the next quarter the amount of oil was reduced to a still lower point, 4.14; the amount of acid was increased to 7.05 and the recovery went up to 86.49. Then you were increasing the acid, reducing the oil and increasing the recovery? Isn't that right?

A. Yes, sir.

X-Q. 68. And then the fourth quarter the oil was slightly increased, 4.78, the acid was still more increased 8.45, and the recovery went down to 84.97, although not very much. There we find a slight increase of oil, an increase somewhat greater in acid, and a slight falling off on the recovery. Doesn't that indicate that you were getting in these two quarters, nearer to good conditions by diminishing the oil and increasing the acid?

Frank R. Wicks.

A. Yes, it would appear that way from this statement. I think, however, that at least a portion of the improved results were due to improving mechanical conditions.

X-Q. 69. Now, how long did you stay with the Butte & Superior?

A. Until April, 1915.

X-Q. 70. And it was during the year 1915 that the oil was brought down to 1.49 pounds per ton; the acid maintained practically at 7.81 pounds per ton and the apparent recovery was up to 90.18 per cent per ton. That was a very great improvement, wasn't it?

A. Yes, sir, it was a very considerable improvement.

X-Q. 71. And that result was obtained with an ore vastly richer in metalliferous mineral contents than any of the ores that you referred to in this table, exhibit 191, was it not?

A. Yes, but an entirely different ore.

X-Q. 72. I won't ask you about metalliferous content of that ore because Mr. Dosenbach will furnish it. I suppose you haven't anything at hand that will give it?

A. No, I haven't that figure. I can say, however, that our records that were kept at that time, while I was there, were correct within the best of my knowledge.

WITNESS EXCUSED.

Edward W. Engleman.

EDWARD W. ENGLEMAN, recalled for further direct examination, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Mr. Engleman, is it not true that in the operation of your flotation plant the following factors are liable to variation: first, the tonnage fed to the plant per unit of time, 24 hours being the usual unit employed?

A. It is.

Q. 2. Is the kind of oil used subject to variation?

A. Very slight variation.

Q. 3. At your plant?

A. Yes, sir.

Q. 4. And the duration and degree of agitation and aeration?

A. Fairly constant.

Q. 5. How about the kind and quantity of reagents, other than oil?

A. We don't use any.

Q. 6. You dont' use any at all?

A. No.

Q. 7. How about the temperature of the pulp?

A. Does not change.

Q. 8. The percentage of moisture in the feed?

A. Varies slightly.

Q. 9. The percentage of sulphide in the feed?

A. Varies slightly.

Q. 10. The quantity of oil used?

Edward W. Engleman.

A. Varies slightly.

Q. 11. Now, in your plant when using the minimum efficient quantity of oil, if all conditions above that I have just mentioned remain constant except the percentage of water in the feed and the quantity of oil used, what change do you make when the percentage of water in the feed increases?

A. Increase the oil.

Q. 12. Now, in your plant when using the minimum efficient quantity of oil if all conditions remain constant except the percentage of sulphide in the feed and the quantity of oil used, what change do you make when the percentage of sulphide in the feed increases?

A. Increase our oil.

Q. 13. I think you have compiled some tabulations from your records, haven't you, showing the relation between percentage of sulphide and oil, quantity and per cent of water and oil quantity?

A. I have.

Q. 14. Are these compiled from the original records?

A. They are.

Q. 15. And to your knowledge they are correct statements of the matters set forth?

A. They are.

Q. 16. Do they cover the two departments of your mill, the vanner concentrate and the slimes plant both?

A. Yes, I have tabulations here for the entire year of 1916 on our retreating plant feed and the same period on our slimes vanner tailing feed.

Edward W. Engleman.

Q. 17. And if requested to you can supplement these tables by additional information from the records you have with you?

A. Yes, sir.

MR. SCOTT: I offer this tabulation in evidence, one entitled "Ray Consolidated Copper Company, Hayden plant, data compiled from monthly statements form number 62R, showing results of operation of vanner concentrate retreatment plant during the year 1916."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 192.

MR. SCOTT: And the second tabulation entitled "Ray Consolidated Copper Company, Hayden plant, data compiled from monthly statements, form 62R, showing results of flotation operation for ten-day periods during the year 1916." "Slimes vanner tailing plant."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 193.

Edward W. Engleman.

CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 18. Taking up exhibit 192, what does the last column show?

A. Per cent total copper and iron in feed.

X-Q. 19. And those are the only two minerals that are represented in the metalliferous mineral?

A. Practically so.

X-Q. 20. To any substantial extent?

A. Yes, sir.

X-Q. 21. So that instead of showing the sulphide you merely show the minerals that are represented in the sulphide; in this table?

A. Yes, sir.

X-Q. 22. Why didn't you show the sulphides?

A. Because I have these assays for every day of the operation during that year and they are reported as copper and iron and not as iron sulphide.

X-Q. 23. Now, this last column is the sum of the two columns before it? Is that right?

A. Yes, sir.

X-Q. 24. Now, these pounds of oil per ton, how do you figure that?

A. Pounds of new oil added per ton of feed treated.

X-Q. 25. And this first column represents—is that "dates"—can't be dates of course?

A. This statement is made up of ten-day periods and period No. 1 is therefore the first ten days and period No. 2 represents the second ten days.

Edward W. Engleman.

X-Q. 26. Where does this start?

A. January 1st, 1916.

X-Q. 27. And does it run consecutively?

A. Yes, sir.

X-Q. 28. And this last period 36?

A. That is December 20th to 30th, or 31st.

X-Q. 29. December what?

A. It is the last ten days in December, 1916.

X-Q. 30. Now, let us take the other one, 193, I don't read on this statement what it is.

A. Slime vanner tailings plant, I think you will see it up there.

X-Q. 31. It is written in ink?

A. Yes, sir.

X-Q. 32. Does that commence with January 1, 1916?

A. It does.

X-Q. 33. I notice that the fourth item of the fourth horizontal line is shown in blank. What is the reason for that?

A. The fourth item and also the 20th item are blank. I could not find the ten day reports for that, but I have the daily operations which go to make up that ten day report and I did not have time to figure it in order to tabulate, but I have it.

X-Q. 34. Will you supply that deficiency in order to complete the record?

A. Yes, sir.

X-Q. 35. That applies to all of the blanks, these two sets of blanks, does it not?

Edward W. Engleman.

A. Yes, sir.

X-Q. 36. Now, as to the other one, the vanner concentrate retreatment plant, I notice that there are some blanks?

A. The last blank or period 36, I did not tabulate that because on the last day of December in this plant we added over one per cent of oil and it would not be fair to add that in that tabulation.

X-Q. 37. But the other blanks you can supply just as you did before?

A. Yes.

X-Q. 38. I wish you would do so.

A. All right.

MR. WILLIAMS: I think with the same reservation—of course I have not had time to study these—I will suspend the cross-examination.

WITNESS EXCUSED.

J. T. SCHIMMIN, called as a witness in behalf of the defendant, being first duly sworn, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Will you please state your full name?

A. J. T. Schimmin.

Q. 2. What is your occupation?

A. Mill superintendent for the Butte & Superior Mining Company.

Edward W. Engleman.

Q. 3. And how long have you had experience with flotation concentration?

A. Since in September, 1912.

Q. 4. In the operation of the Butte & Superior flotation plant I will ask you whether the following factors are liable to variation: first, the tonnage fed to the plant per unit of time?

A. Yes.

Q. 5. And how about the kind of oil?

A. Yes.

Q. 6. That varies too?

A. Yes.

Q. 7. And is there any variation in the duration and degree of agitation and aeration?

A. Yes.

Q. 8. Is that variation marked, the speed of agitation?

A. Yes, it is.

Q. 9. Over what periods does it vary—vary from higher to lower I mean?

A. Oh, no, the amount of agitation does not vary. It is constant.

Q. 10. The agitation and aeration are constant?

A. Yes, they are constant.

Q. 11. The kind and quantity of reagents other than oil? Is there some variation in that?

A. But very little.

Q. 12. Temperature of the pulp?

A. Very little variation in the temperature.

Q. 13. And is there some variation in the percentage of moisture in the feed?

Edward W. Engleman.

A. Yes, at times there is.

Q. 14. And how about the variation in the percentage of sulphide in the feed?

A. Yes, that varies to a certain extent.

Q. 15. And how about the variations in the quantity of oil used?

A. Well, that varies slightly, depending upon the tonnage and so forth.

Q. 16. Now, in your plant when using the minimum efficient quantity of oil, if all the conditions I have just mentioned remain constant except percentage of water in the feed and the quantity of oil used what change do you make when the percentage of water in the feed increases?

A. We increase the oil.

Q. 17. Now, in your plant when using the minimum efficient quantity of oil if all conditions remain constant except percentage of sulphide in the feed and the quantity of oil used what change do you make when the percentage of sulphide in the feed increases?

A. Increase the oil.

Q. 18. Have you compiled a tabulation from your records showing the relations between percentage of sulphide and oil, quantity and per cent of water and oil quantity?

A. I have, yes, sir.

Q. 19. Did you compile this or have it compiled under your direction?

A. I have had it compiled under my direction.

Q. 20. From the original records of the company?

Edward W. Engleman.

A. Yes.

Q. 21. And you are able to testify that this is an accurate statement of the matters set forth?

A. Yes.

Q. 22. And you do so?

A. Yes.

MR. SCOTT: I offer this tabulation entitled "Butte & Superior Mining Company, data compiled from original records of flotation plant operations, month of November, 1916, flotation plant feed."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 194.

MR. SCOTT: You may cross-examine.

#### CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 23. In the second column in the tabulation produced by you, exhibit 194, the first column following the date, the first item is 1.67 pounds of oil per ton?

A. Yes.

X-Q. 24. Is that new feed?

A. That is new flotation feed, yes; new feed.

X-Q. 25. And what oil was used then?

A. Pine oil.

X-Q. 26. And throughout the month of November that is here tabulated what oil was used?

A. Pine oil with the exception of—I don't remem-

Edward W. Engleman.

ber exactly—it was about 36 hours I think when reconstructed oil, compounded oil, was used.

X-Q. 27. Can you tell me when this was, these operations, because having a new and totally different oil introduced it might introduce a variable factor?

A. No, I can't tell you the exact date without looking it up.

X-Q. 28. Will you look that up?

A. Yes.

X-Q. 29. Of course that would take a day and a half and might seriously change one of these figures; you appreciate that?

A. Yes.

X-Q. 30. What other reagent or reagents were used during this period of November, 1916?

A. Sulphuric acid and copper sulphate solution.

X-Q. 31. Was the amount of sulphuric acid and copper sulphate solution variable during this period?

A. Slightly, yes.

X-Q. 32. To what extent did it vary? Take first the sulphuric acid?

A. Well, it would probably vary from six and a half to eight and a half pounds per ton.

X-Q. 33. And how the copper sulphate?

A. Probably two one-hundredths of a pound of metallic copper, equivalent to two one-hundredths of a pound of metallic copper.

X-Q. 34. And how about its variation?

A. That is the variation.

X-Q. 35. What was the absolute assay then?

Edward W. Engleman.

A. From eight one-hundredths of a pound to one-tenth of a pound.

X-Q. 36. Now, I notice that you have compiled the zinc sulphide from the assay of zinc. It is true, is it not, that there are small quantities of other sulphides in your ore?

A. Yes.

X-Q. 37. And these other sulphides are variable, are they?

A. The sulphides vary but little. In fact, you might call them almost constant.

X-Q. 38. And what would be the constant or nearly constant, approximately, that would have to be added to the zinc sulphide to represent the total sulphides in the ore?

A. You mean the percentage that should be added to represent the total?

X-Q. 39. Yes.

A. I should say between six and seven per cent.

X-Q. 40. Have you a tabulation covering this month giving the other factors such as appear on the large sheet containing the Butte & Superior operations which has been put in evidence? Have you a table of that character?

A. Yes, I haven't got it with me though.

X-Q. 41. Will you produce it and let me have it?

A. Yes, I will.

MR. WILLIAMS: The cross-examination is suspended.

WITNESS EXCUSED.

Ralph Augustus Conrads.

R. A. CONRADS, recalled, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Mr. Conrads, will you tell me whether in the operation of the flotation plant where you are employed the following factors are liable to variation: tonnage fed to the plant per unit of time?

A. Yes, sir.

Q. 2. That is subject to variation?

A. It is subject to variation.

Q. 3. How about the kind of oil used? Is that also a variable?

A. The kind of oil used is variable to a degree. That is we have certain standard oils which we ordinarily use, but at times we are forced to make changes, though we do not make any radical changes in that ordinarily.

Q. 4. Is there much or any variation in the degree of agitation or aeration?

A. No, that is fixed with us.

Q. 5. And the variation in kind and quantity of reagents, other than oil?

A. There is a variation in the quantity, but not in the kind, there is not.

Q. 6. How about the temperature of the pulp?

A. We run at atmospheric temperature. We don't artificially heat the pulp.

Ralph Augustus Conrads.

Q. 7. You don't use artificial heat?

A. Do not.

Q. 8. So it is subject to variation from any sources whatever other than the climate?

A. It is subject to slight variations, but it is not noticeable or hardly considerable.

Q. 9. Does the percentage of moisture in the feed vary?

A. It does, yes.

Q. 10. Percentage of sulphide in the feed?

A. That also varies.

Q. 11. Quantity of oil used?

A. And the quantity of oil is variable.

Q. 12. Now, in your plant when using the minimum efficient quantity of oil and all conditions that I have just mentioned remain constant except percentage of water in the feed and the quantity of oil used, what changes do you make when the percentage of water in the feed is increased?

A. Increase the amount of oil.

Q. 13. In your plant, while using the minimum efficient quantity of oil and all conditions remain constant except percentage of sulphide in the feed and quantity of the oil used, what changes do you make when the percentage of sulphide in the feed increases?

A. We increase the oil also.

Q. 14. You have made a tabulation, have you, from your records showing the relation between percentage of sulphide and oil quantities, and percentage of water and oil quantities?

Ralph Augustus Conrads.

A. Yes.

Q. 15. During the period covered by this compilation was the same character of oil used throughout?

A. There was a certain variation. I made one chart which covered the entire period of the plant during which they have treated or retreated low-grade concentrate, the kinds of oil have varied in that, and I have taken these monthly averages and made a compilation on that basis. I have another in which the kinds of oils were not varied a great deal. It is practically a crude mineral oil with creosote. That is for a 28-month period, September, 1914, to December, 1916, inclusive.

Q. 16. You compiled this yourself from the original records?

A. I did, yes, sir.

Q. 17. And it is correct?

A. To the best of my knowledge it is correct.

MR. SCOTT: I will offer this tabulation entitled "Utah Copper Company, Magna Plant, Metallurgical Department, data compiled from statements giving average results by months of operations of vanner concentrate flotation plant, September, 1914, to December 1st to 24th, inclusive, 1916."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 195.

Q. 18. You also compiled this second statement which you handed to me?

A. I did.

Ralph Augustus Conrads.

Q. 19. And is it correct and accurate?

A. To the best of my knowledge and belief, it is.

MR. SCOTT: I offer the second report produced by the witness, entitled "Utah Copper Company, Magna Plant, Metallurgical Department, data compiled from original records of operation of vanner concentrate flotation plant for the year 1915, etc."

Table admitted without objection, marked DEFENDANT'S EXHIBIT 196 (two sheets).

Q. 20. You compiled this third statement from the original records, did you?

A. Yes, I did.

Q. 21. And is it true and accurate?

A. Yes, to the best of my knowledge and belief it is.

MR. SCOTT: I offer the third statement produced by the witness, entitled "Utah Copper Company, Magna Plant, Metallurgical Department, date compiled from original records of operation of vanner concentration flotation plant for the year 1916."

Table admitted in evidence marked DEFENDANT'S EXHIBIT No. 197 (2 sheets).

MR. SCOTT: Mr. Conrads wants to correct an answer that he made before, Mr. Williams.

Q. 22. What was the answer?

A. There is just one question; in reading over my former testimony, in that, while my answer is correct, it is not quite as accurate as I would like to put it, and I would like to make the correction accordingly.

Ralph Augustus Conrads.

MR. WILLIAMS: You may do so. Will you give me the number of the answer?

THE WITNESS: Yes, sir; it is page 560, question No. 306. You asked: "That sludge tank, is that full—full to overflowing?" and my answer was "No, I have never seen the sludge tank full; that is, it is a perfectly clean fall; that is, it does not interfere in getting the samples." I want to correct that statement simply in this, that I have a very few times seen that sludge tank overflowing a little froth. Now, if you will look at the previous questions, we were considering the matter of sampling the circulating feed, and where that sample is got, and when you asked the question I had in mind the sampling, and my answer there was with that in mind. I have never seen the sludge tank full of pulp, and very few times have I seen it overflowing froth, and we are very careful in taking that sample that it is never full, so as to interfere with the sampling of the stream as it drops from the launder into the tank. I wanted to be a little more accurate in that, as I noticed that, while practically true, it was not as accurate as I wished it stated. That is all, Mr. Williams.

Ralph Augustus Conrads.

CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 23. Now, in the first of these tables which you produced, exhibit No. 196, you gave the variation in the kind of oil; in this period, covering from January 12th, 1916, to December 23d, 1916, you made, of course, certain variations in the oil, did you not?

A. There were some variations, yes, sir.

X-Q. 24. Do you think you have previously testified as to what those variations were?

A. Well, I gave you, if you will remember, a note of the variations asked for, and, as I stated in my direct examination, there were no extreme or radical variations. We used through that time, practically all of the time—I think I am safe in saying all of the time—crude petroleum oil with creosotes. Now, those creosotes were varied to a certain degree, though not radically.

X-Q. 25. And all of those creosotes, of course contained soluble constituents?

A. Yes, sir.

X-Q. 26. And the other oil, the crude petroleum oil?

A. It is a top petroleum oil, that is, a crude oil with the lighter groups removed; practically all the gasoline and kerosene are removed.

X-Q. 27. Did you ever determine whether or not there were any soluble constituents in those oils?

Ralph Augustus Conrads.

A. No, but from the very nature of them, it is safe to say that there would be practically none.

X-Q. 28. Could you give me any figures as to the percentage of soluble constituents in the creosote?

A. No, I could not.

X-Q. 29. Now, the second table that you have produced, exhibit 197.

A. That is the third table, Mr. Williams.

X-Q. 30. Well, the one that I am referring to is No. 197, data compiled from the original records of the operations of the vanner concentrate flotation plant for the year 1916.

A. There are two of those for that year. Exhibit No. 196 covers the days in the year 1916 on which the percentage of solids in the flotation feed was not under 31% nor over 33%, while in exhibit 197 the compilation embraces the days of the year on which the percentages of mineral—that is, 100% minus the percent of the insoluble matter, in the feed, was between 24.5 and 25.5.

X-Q. 31. Are these the assay returns of the insoluble that you give in this table, exhibit 197?

A. Yes.

X-Q. 32. And is it true of your ore that the assay returns of insolubles give all of the constituents except the sulphides?

A. No, but I took that for the reason that, on account of the nature of our ore, I think that this will more nearly represent it—that is, represent the total amount or percentage of mineral than by attempting

Ralph Augustus Conrads.

to calculate it from the copper and iron of the assay.

X-Q. 33. What are the constituents of your ore? which are present in the form of sulphides?

A. Principally pyrite, chalcopyrite and chalcocite, with certain other minerals entering into it in a minor degree. The reason that I did not calculate them on the basis of the assay for copper and iron was because the ratio of the amount of chalcocite and chalcopyrite and pyrite, for example, are not constant from one day to another or from one time to another.

X-Q. 34. Is the ratio of sulphide—or is the proportion of sulphide clearly indicated by the amount of insoluble in the assay returns?

A. It is not absolutely accurate, though I believe that it is a more accurate way of getting that ratio than any other that I know of, without analyzing, and every one specially, which analyses we do not have.

X-Q. 35. That is, with the assays before you, you selected this as the one that would give us the nearest estimate of the proportion of metalliferous mineral in the ore; is that correct?

A. The proportion of sulphide or metalliferous mineral in the ore, yes, sir. While that is not absolutely accurate, I take it because I think it is the most nearly accurate of any way that we have at hand.

X-Q. 36. Now, will you give me a typical assay, so that we can see all the conditions that entered into your determination?

A. You mean to take one of these days and give you the assays?

Ralph Augustus Conrads.

X-Q. 37. Yes.

A. What day would you like, Mr. Williams?

X-Q. 38. Take about the middle of the period. I don't see the months.

A. The month is indicated by the first <sup>figure</sup> ~~degree~~ of the two in the left-hand column.

X-Q. 39. Well, we will take about the middle of July. About 6/24—June 24th will answer.

A. June 24th. The heading on that day assayed 6.64% copper, 6.54% iron and 75.10% insoluble. The per cent of solids is on the sheet at 29.65, and the pounds of oil per ton were 3.40.

X-Q. 40. And that is all your assay shows?

A. In the heading, yes, sir.

X-Q. 41. You might complete it by giving me the assay of the concentrates and of the tailings on that day.

A. The concentrate assayed 25.98% copper, 23.25% iron and 16.13% insoluble. The tailing assayed .35% copper and .76% iron.

X-Q. 42. Percentage of insoluble, have you that in the tailing?

A. No, sir; we never run the tailing for insoluble.

X-Q. 43. Now, let us take September 1st.

A. September 1st, 1916; the heading was 7.68% copper, 6.08% iron and 74.70% insoluble. The concentrate, 29.12% copper, 20.62% iron and 18.43% insoluble; tailing, .24% copper, and .51% iron.

X-Q. 44. Now, let us take the last date, December 18th.

Frank G. Janney.

A. December 18th, the heading assayed 7.60% copper, 5.78% iron and 74.93% insoluble; the concentrate, 30.95% copper, 20.32% iron, 16.60 insoluble; and the tailing, .138% copper and .56% iron.

MR. WILLIAMS: The cross-examination of Mr. Conrads will be suspended for the present until we have further studied the tables.

FRANK JANNEY, after being duly sworn as a witness for defendant, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. State your full name.

A. Frank G. Janney.

Q. 2. What is your occupation, please?

A. General superintendent of mills for the Utah Copper Company.

Q. 3. The mills at Garfield, Utah?

A. At Garfield, Utah.

Q. 4. They are known as the Magna plant and the Arthur plant, are they not?

A. They are.

Q. 5. How long have you been occupied in practising flotation, or how long does your knowledge of flotation extend?

A. Since the early part of 1912. .

Q. 6. And you have been continuously engaged in

Frank G. Janney.

the practice or trying out of flotation processes ever since?

A. I have.

Q. 7. Will you state whether it is true that in the flotation process the following factors are liable to variation; first, the tonnage fed to the plant per unit of time.

A. Yes.

Q. 8. And how about the kinds of oil used?

A. They are variable.

Q. 9. You might state to what extent that is variable, and what kind of oil is used generally.

A. Well, they are variable simply in the kind, that is all.

Q. 10. How about the duration and degree of agitation and aeration?

A. It is constant.

Q. 11. And the kind and quantity of reagents other than oil?

A. Variable.

Q. 12. And the temperature of the pulp—of course I refer to your own operations.

A. I understand. We operate at atmospheric temperature.

Q. 13. And percentage of moisture in the feed?

A. Variable.

Q. 14. The percentage of sulphide in the feed?

A. Variable.

Q. 15. How about the quantity of oil that you use?

A. Variable.

Frank G. Janney.

Q. 16. Now, in your plant, when using the minimum efficient quantity of oil, if all the conditions we have just mentioned remained constant, except percentage of water in the feed and quantity of oil used, what change do you make when the percentage of water in the feed increases?

A. Increase the oil.

Q. 17. And in your plant when using the minimum efficient quantity of oil, if all factors remain constant except percentage of sulphide in the feed and quantity of oil used, what change do you make when the percentage of sulphide in the feed increased?

A. Increase the amount of oil.

Q. 18. Have you visited several different flotation plants and observed their operation?

A. I have.

Q. 19. Are you familiar with the way in which these flotation operators generally tell when they need to change the quantity of oil—when the quantity of oil should be changed?

A. I am in a general way.

Q. 20. In a general way what does occasion their adjustment of the oil quantity?

A. The dilution.

Q. 21. Any other thing?

A. The agitation and the amount of sulphide.

Q. 22. You have made some tables, haven't you, of the operations conducted under your charge, showing the relations between percentage of sulphide and oil quantities and percentage of water and oil quantities?

Frank G. Janney.

A. I made one tabulation of the variation of the pounds of oil to percentage of sulphides only.

Q. 23. Is this tabulations made from your original records?

A. It is.

Q. 24. And you have personal knowledge that it is correct?

A. I have.

MR. SCOTT: I offer this tabulation entitled "Utah Copper Company, Arthur Plant, metallurgical department, data compiled from original record of operation of flotation plant treating original slime feed."

Tabulation admitted in evidence and marked DEFENDANT'S EXHIBIT 198.

Q. 25. Will you just explain, Mr. Janney, what this tabulation is intended to exhibit?

A. This tabulation was gotten up from which a graphic chart was drawn and refers only to the pounds of oil per ton and the percentage of solids. The copper and iron values having no value in the graphic charts.

Q. 26. You mean the graphic chart which was made?

A. From this data.

Q. 27. Was data only on the dilution?

A. The same thing.

Q. 28. And no account was taken of the mineral?

A. No.

MR. SCOTT: You may cross-examine.

Frank G. Janney.

CROSS-EXAMINATION.

BY MR. WILLIAMS:

X-Q. 29. As I understand it this chart that you have produced represents proceedings with an invariable oil mixture, is that right?

A. Invariable oil mixture.

X-Q. 30. Now, what was that oil mixture?

A. 95 per cent Barrett number 4, 5 per cent Yar-yan pine.

X-Q. 31. Barrett number 4 is what kind of an oil?

A. Creosote oil.

X-Q. 32. And that had a soluble constituent?

A. It has.

X-Q. 33. And the pine oil is to some extent soluble, in the proportions used?

A. It is.

X-Q. 34. And other conditions then, thickness <sup>of</sup> pulp and richness of ore, did they have any influence on the increase or diminution of the amount of oil?

A. Change in feed and tonnage.

X-Q. 35. Anything else?

A. No.

X-Q. 36. Of course you are referring to the operations in your plant?

A. Yes.

X-Q. 37. How about the variation in the amount of gangue in the feed; ~~that doesn't~~—doesn't that vary the oil proportions?

A. It does through the dilution.

Frank G. Janney.

X-Q. 38. Aside from the dilution and considering it as a matter of solids, the amount of gangue in the feed is quite an important item in itself, is it not, in varying the amount of oil?

A. I don't know just exactly what you mean.

X-Q. 39. I suppose that may be said to be the reverse of the condition of richness of ore. That is to say if your ore contains more mineral and less gangue, that is one condition?

A. Yes, sir.

X-Q. 40. Now you might have a condition where there was less mineral and more gangue, then the ore would not be as rich?

A. Yes.

X-Q. 41. Now, under these conditions you have to change the oil?

A. Yes.

X-Q. 42. So that to that extent the increase and diminution of gangue is a variable although related to the decrease and increase of metalliferous mineral? That is right, is it not?

A. Yes.

X-Q. 43. Now, how about the character of the gangue? Doesn't that change the oil proportion?

A. Not on our ore.

X-Q. 44. Not on your ore?

A. No.

X-Q. 45. And you refer to the operations of the Arthur plant?

A. Yes.

Frank G. Janney.

X-Q. 46. How about the fineness of the grinding of the gangue? Isn't that a factor?

A. Not on our ore, I do not think.

X-Q. 47. That is to say that is not a variable in your ore?

A. It is not a variable, very constant.

X-Q. 48. You testified, did you not, in the suit of the Minerals Separation Limited against the Miami Copper Company?

A. I did.

X-Q. 49. And in your testimony there you described the great troubles that you had in correcting the faults of the plant of the Butte & Superior Copper Company, the flotation plant, did you not?

A. I did.

X-Q. 50. You might give me the period when you were correcting these faults, generally?

A. From July of 1912 to—

X-Q. 51. (Interrupting.) Just to refresh your memory, what you answered in the Miami case was: "I was sent to investigate the Butte & Superior process in the early part of 1912. I think it was in the month of June or July; maybe May; I will not be positive about that point." I have read your testimony correctly?

A. Yes, sir. I looked it up since then, it was July.

X-Q. 52. And how long did you continue in this struggle which you so fully outlined in the Miami case of getting that plant into good working condition?

A. About the middle of 1913; I am not positive

Frank G. Janney.

when I made my last trip to Butte. I know it was in the year 1913.

X-Q. 53. Reading from your testimony in the Miami case, question 94: "Now, will you tell us the date upon which the results were of such a character as to make it certain that flotation was advantageous? A. It was in the month of April or May of 1913." Have I read your testimony correctly?

A. Yes, sir.

X-Q. 54. And is that a correct statement?

A. It is.

X-Q. 55. I also read you question 95: "And what did you do in the way of oils? A. We tried several different kinds of oil, oleic acid, various grades of oleic acid, pine tars and pine oils and wood tars. Q. 96. Can you make a statement as to the comparative results of using pine oil and oleic acid? A. With pine oil we found that we could get a very good grade, but we were unable to make a good tailing. With oleic acid we could make a very good tailing, but only a fair grade." Have I read your testimony correctly?

A. You have.

X-Q. 56. And that needs no correction, I take it?

A. None at all.

MR. WILLIAMS: That is all.

#### RE-DIRECT EXAMINATION.

BY MR. SCOTT:

R-Q. 57. Were you in charge of the operations of the Magna plant from September, 1914, down to July, 1915?

Prof. Arthur Fay Taggart.

A. I was.

R-Q. 58. You are familiar with this tabulation that has been made, I take it?

A. Yes.

R-Q. 59. Are you in a position to verify these reports, state that they are accurate and true?

A. To the best of my knowledge they are.

MR. SCOTT: There is no further objection to these.

MR. WILLIAMS: No further objection upon the ground that the witness is not able to testify to the facts.

(Exhibit 35.)

WITNESS EXCUSED.

PROF. ARTHUR FAY TAGGART, recalled, testified as follows:

DIRECT EXAMINATION.

BY MR. SCOTT:

Q. 1. Professor Taggart, have you made any investigation based on the facts set forth in these compilations which are in evidence as exhibits 191 to 198?

A. I don't know the exhibit numbers. I have made some compilations, some graphs based on the data that has just been presented regarding the relation between the percentage of oil and the dilution of the pulp and the percentage of sulphide in the pulp.

Prof. Arthur Fay Taggart.

Q. 2. Well, what conclusions have you arrived at from your investigation?

A. I have arrived at the conclusion that—or at least I have confirmed the conclusion that there is a relation and a very decided and strong relation between the percentage of sulphide in the feed or the variations in this percentage and the variations in the quantity of oil required, other things being constant, and also between the variations in the dilutions of the feed and the quantities of oil required, other things being constant. I am offering this data rather to satisfy Mr. Williams I think in regard to an inquiry in my previous testimony as to whether these statements that I was making were not wholly theory and as to whether it was possible to confirm them with any experimental data. He did not include mill operations, but the mill operations being more closely at hand, I investigated those and I have here a series of charts which show unmistakably a direct relation between the pounds of oil used and the dilution of the pulp, other factors being constant, and the pounds of oil and the percentage of sulphide in the pulp, other things being constant. Now I wonder if I might explain a little bit here regarding the curves compiled from empirical data. If your honor will notice this particular sketch which we will offer later you will see that there are points scattered around over this sheet and that through them I have drawn a curve. The curve does not go through every point but is the average curve of these points. It has been put through according to the

Prof. Arthur Fay Taggart.

accepted method of putting curves through points representing the result of investigations and such curves leading, if desired, to the formulation of empirical formulae to represent the relation between the two particular variables investigated. Now, just to show you that every fact represented there does not lie di-

*on the curve I would like to cite a couple of  
P. 3531, L. 9, insert "familiar to all of us and which are"  
after "are"*

temperature with the seasons. For various parts of the country there are well established average curves of temperature ranging from season to season, and if I may represent here about how one of these curves goes I think it will perhaps make it clear. If each one of these divisions represents a particular division of the year as for instance, if this represents February, this March and this April, May, June, July, August, and this represents degrees of temperature, we will call these, we will say forty, fifty, sixty, seventy, and up to eighty, we know that in certain communities at least from February through March, through April and May there is a gradual increase in the temperature which would be represented in some such fashion as this. Suppose that during February the average temperature were  $40^{\circ}$ ; during March the average temperature were fifty degrees, then a point would be placed there, and during April it were 55 degrees, another point would be placed at the ordinate representing May, and if in May it were sixty and

Prof. Arthur Fay Taggart.

June sixty-five, and July seventy, then the curve that would represent the average would be drawn in actually a straight line for the average through these points. Now, nobody would expect, looking at that average curve that all the days in March were going to have a temperature of 50 degrees. If we plotted along here the temperature of the days in March they would be found to spot around the average in that case; and, similarly, if we plotted the days in April, and it is quite easily recognized that there is an average advance of temperature through these months. Another case, and one upon which a great deal more money is invested than this particular case of temperature, and one in which the ranges are much greater, is the case of life insurance premiums based on the average life, and life insurance premiums have decreased as the years have gone on, due to the fact that the average age of people in certain lines of life is increasing. Now, we know very well that if we draw a curve representing—take one thousand people, and if we draw a curve representing the average age of life that it will not mean at all that certain people are going to live until exactly that age. There are going to be deaths of course from an hour or a shorter moment after birth to even very considerable old age. These are going to range through large distances and yet for each year that those data are compiled there are going to be deaths all through these different ages and yet the average curve through there will show that as we go from 1912 to 1913 and from 1913 to 1914 there

Prof. Arthur Fay Taggart.

is a gradual increase in the average age; and that average curve is so well recognized that the life insurance companies expend or promise to expend enormous sums of money on the computations made by their actuaries. These computations are merely straight lines, average lines drawn through these experimental points. Now, I hope with this explanation that I may be able to show the results of plotting some of these facts that have just been represented, and to show your honor that the curve drawn through in each particular case represents the average of all these points which are plotted on the graph. The first curve which I have here is that of the Utah Copper Company, Arthur plant, flotation treatment of original slime feed for the months of September and October, 1916, omitting October 8th to 12th inclusive when the oil mixture was changed, the data being compiled from original records of operation, these records being already in evidence, presented by Mr. Janney.

MR. SCOTT: I offer the table just described by the witness.

MR. WILLIAMS: No objection.

The graph admitted in evidence and marked DEFENDANT'S EXHIBIT 199.

A. Now, if your honor will notice this particular curve it increase, that it rises toward the right. If you will notice down at the bottom of this sheet are certain numbers and written above that are the words "pounds of new oil used per ton of original feed," and

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that these numbers increase towards the right. That means a point which was plotted on the chart anywhere above that three, for instance, represents that three pounds of oil were used. That is if a point appears anywhere along this line vertically above the three, it means that three pounds of oil were used. Then, on the left hand margin of the sheet are two series of numbers, those to the left reading 80, 85 and 90, and representing the per cent of water in the feed. They read upward 80, 85 and 90, indicating that that particular square increases upwards. The complimentary square of that is put beside it, that is 10, 15 and 20. The three numbers reading downwards representing percentage of solids in feed. Of course the statement of our constants, if put in terms of percentage of solid in the feed, would be that the pounds of oil necessarily varied inversely as the percentage or solid in the feed; but it is rather easier to speak of the direct variation, rather than of the inverse variation. Now, your honor will notice that as this curve passes to the right it rises and if we take first any point on the vertical line running upwards, this one representing one pound of new oil used per ton of original feed, and then run over to the left at the <sup>at</sup> level, the square representing the percentage of water in the feed, you will see that the percentage of water there is about eighty-two per cent. In other words, for a percentage of water eighty-two per cent of the total pulp fed to the mill an average amount of one pound of oil per ton of solid feed to the mill was used. If now your

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honor will go out to the vertical line over the number two on the lower scale and follow that line up to its intersection with the straight line which has been drawn and then follow from that point to the intersection to the left and read on the scale of percentage of water you will see that that reads about eighty-four and a half. In other words when the dilution of the pulp has increased from eighty-two to eighty-four and a half, the average amount of oil necessary in that particular mill had increased to two pounds. There is a direct relation there, other things being approximately constant, between the amount of oil needed and the amount of water present in the pulp. That same thing is borne out in all these other statements, as I will represent the curves to you.

Q. 3. Now, Professor Taggart, would it be practicable to explain, so that we can get some idea of the manner of laying out these curves and what these numbers mean on the different dots?

A. Yes. The numbers I may say on the curves correspond to the numbers in the left-hand column of the particular sheet which goes with it. In other words, those are the data to which these particular dots correspond. For instance, if we take the number 6 at the far left of the chart. The numbers corresponding to this on this sheet are "pounds of oil per ton, 0.82". That is on the sheet entitled "Utah Copper Company, Arthur plant," and there being only one of those.

Q. 4. Is that the last one?

A. The last one that was offered.

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THE WITNESS: Now, if you will look at this No. 6, you will note that the dots to the left there refer to the date of September 6th, and there in the next to the last column is "Pounds of Oil per Ton, 0.82." Now, going to the scale at the bottom of the sheet and moving out here to a point between 0.75 and 1—The point 0.82 represents the distance to the left at which you must plot this 0.6. Now, corresponding with 0.82 there is in the last column the number 19.30, which represents the percentage of solids in the feed; and going then on to the scale at the left end of the chart between 15 and 20 in the column "Percentage of Solids in Feed," down near the 20 in order to get at 19.30,—That is the altitude of this charge at which this same spot should be plotted.

Now, if we follow that horizontally, then, from that point and vertically upward from the point right over 0.82 which we have previously located, at the intersection of those two lines is the point where that figure 6 is to be plotted. In other words, if we work this thing backwards, you take the point 6, and you can read that it means 0.82 pounds of oil were used, and the percentage of solids in the feed was 19.30, and the same method is followed in plotting, as it is called, all these points from the sheet, and all these different values from this sheet of the different dots represented in their proper position by this series of dots on the chart, showing by their number the particular date which they represent—those numbers which are separate being for the month of September, and those which

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are preceded by the number 10, representing the different days in the month of October.

This particular chart extends from the first of September to the end of October, 1916.

Now, the method of putting the curve through those points is one that was developed by an engineer by the name of Steinmetz, who is probably the most famous experimental engineer in the country. He is one of the experimental engineers for the General Electric Company, and one of the lines in which he has been very much interested is the mathematical side and the experimental side of electricity. Now, his idea is that, when you have a series of points such as this presented here, and wish to <sup>plot</sup> pass through them an average curve, as, for instance, if I plot points all around here in that fashion—Of course for rough work you can just size up by the eye what straight line will approximate the average of those points—and it would pass through in some such fashion as that. If, however, you want accurate results, the method recommended by Steinmetz is to divide these points approximately into equal lots, as it were, that is, into two lots containing approximately equal numbers of points at either side of a line which is approximately at right angles to the point, and the line should be—the type formula for a straight line is  $Y$ , and the formula is,  $Y$  equals  $AX$  plus  $B$ . Now, if it is necessary, before you plot that particular curve, to determine the coefficient  $A$  of the variable  $X$ , and the constant term,  $B$ ,

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that is done by taking each one of these points to the left of your line separately, and substituting in the value of Y, which is the distance of the point upwards from this horizontal line, which we will say in this case is approximately 2, and substituting in also the corresponding value for X, which in this case would be 1, and we will then have this equation: 2 equals 1A plus B.

Now, if you repeat that for all the points at the left of that line—I will take one other point here for the purpose of illustration; suppose we take the point here, and the value of Y there would be approximately 2.2, and the value of X would be about 3—Of course all these numbers that I am approximating here are taken accurately and directly from the table of the curves—We would have then, for the second equation by which we hope to determine A and B, the equation: 2.2 equals 3A plus B.

Now, if we add together that series of equations, we get, 4.2 equals 4A plus B.

We now pass onto the other side of the line, and repeat the same method of treatment, and I will take two points over there; I will take 2, because this will throw a line in there with at least an average of what I have taken. We will take this point, in which case Y will equal approximately 4, and the equation will be, 4 equals 3.5A plus B, and for the point here we will have, 2.5 equals 5A plus B, and if we take these points together, we get the equation 6.5 equals 8.5A plus 2B.

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Now, by solving those equations we have now two independent equations in A and B, and it is a rule that if you have two independent equations and two unknowns, it is possible, by simultaneous solution of the two equations, to determine the two unknowns. You then go about this solution in this fashion: subtract one from the other, and you get  $4.5A$  equals 2.3, or that A will be equal to  $\frac{2.3}{4.5}$ , which is easily turned into a decimal number.

Then, given that result, you get that B is equal to something over 1, which I will indicate by 1 plus. Then we go back to this equation and substitute the values of A, and we find that  $\frac{Y}{Q}$  is equal to  $\frac{2.3}{4.5} X$  plus 1 plus—that is, something larger than 1; I don't think it is necessary to go through the calculations. All those curves have been calculated through in that fashion; that is the equation and the correct equation for averaging the lines to those points, and it can then be plotted in the light of that equation in some such fashion as that.

Q. 5. THE COURT: What is the object in the end, to show the varying relations between these several factors?

A. Yes, sir, to show that the oil—

Q. 6. To show that there is some constant curve?

A. Absolutely, and it shows in all these charts, not only in regard to the dilution, ~~but in regard to the dilution,~~ but in regard to the percentage of sulphide.

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This is the line of the average when the percentage of sulphide was held practically constant, while some of these other curves were plotted when the dilution was held practically constant, and the only thing plotted were the percentage of sulphide and the amount of oil, and in those cases the same kind of an equation is shown.

Q. 7. Going right back to this exhibit 198,—I want to get onto these curves—On the 28th of September you have got a .99 copper, .93 iron and 12.79 solids?

A. Yes.

Q. 8. Now, you had less metal, so you must have had more water in the solution?

A. More water, yes.

Q. 9. And consequently your oil content runs pretty high?

A. Yes, sir.

Q. 10. Then if we take the one for the 6th, you have got <sup>more</sup> ~~some~~ copper and more iron and more solids?

A. Yes, sir.

Q. 11. That would mean of course less water?

A. Yes.

Q. 12. Your oil content runs down pretty low?

A. Yes.

Q. 13. It is a pretty wide variation, and this is an attempt to balance all these factors?

A. Yes, that is what I say. It is the same question here; it is the same problem which confronts the actuary. He has people dying, children, middle aged people, old people, dying at all ages, yet he balances